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Youth Awareness and Expectations about GMOs and Nuclear Power Technologies within the North American Free Trade Bloc: A Retrospective Cross-Country Comparative Analysis

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Abstract: This study reports on the cross-country heterogeneity in youth awareness and expectations about genetically modified organisms (GMOs) and nuclear power technology (NPT) within the North American free trade area (NAFTA). Models are estimated with data on youth respondents from the USA, Canada and Mexico, using seemingly unrelated bivariate weighted ordered probit regression, with maximum simulated likelihood estimation. Our findings show that the diffusion of technology and information within the trade bloc, for the 20 years prior to the 2015 data collection period, did not significantly contribute to cross-country convergence in youth awareness and expectations about GMOs and NPTs. Indeed, with regard to awareness, compared to youth from the USA, those from Canada show 15% (GMOs) and 7.1% (NPT) more awareness, respectively; while youth from Mexico show 34.4% and 19.5% less awareness about GMOs and NPT, respectively. With respect to expectations about future developments of the two technological artifacts, compared to youth from the USA, those from Canada and Mexico are 34.4% and 39.9% more optimistic about GMOs, respectively, while 15% and 49.7% are more optimistic about NPT. Overall, our findings show that the youth population within NAFTA is 2.5% and 6.7% more optimistic about GMOs and NPT for each level of increase in their awareness about the two technologies, respectively. Theoretically, our results seem to reject the hypothesis of NAFTA being a technology convergence country club in the Schumpeterian view, while seemingly supporting the existence of heterogeneous growth regimes within NAFTA.

Keywords: expectations convergence; NAFTA; sustainable development; technological transfer; youth awareness

JEL Classification: D83, D84, P48, Q01, Q5, Q57

1. Introduction

Free Trade Areas (FTAs) characterized by trade liberalization with national trade policy autonomy are processes through which nations enter into agreements to share a common trade zone, allowing all trading partners to benefit from a larger market with lower trade barriers [1]. By allowing member countries to trade with less friction, FTAs theoretically contribute over time to bloc convergences in economic, social and environmental factors [2,3]. Indeed, within the context of international trade, "*Integration theory identifies the economic effects—both short-term static and long-term dynamic—of particular stages of integration processes which should be expected within integrating economies*" [4].

It is generally believed that technological innovation and diffusion are key determinants of economic development [5], cross-country growth differences [6] and catching up [7]. However, most of the literature on cross-country integration and (non-)convergence focuses exclusively on factors such as price [8], income [9], real exchange rate [10], economic freedom [11] and other macro-economic indicators [12]. Very little is known about cross-country differences and convergence in individuals' awareness and expectations about specific technological artifacts within integrated economies. Since convergence between integrated economies relies heavily on the diffusion of technology [13,14], knowledge [15], and increased volume of trade [16], convergence in technological awareness and expectations should be an important precondition for actual technological and economic convergence.

In the field of information technology, "innovation" is defined as "an idea, practice, or object that is perceived as new by an individual or another unit of adoption", while "diffusion" is "the process by which an innovation is communicated through certain channels over time among the members of a social system" [17]. Therefore, technological innovation and diffusion are concerned with "potential users making decisions to adopt or reject an innovation based on beliefs that they form about the innovation" ([18], p. 90). As such, changes in individual perceptions and attitudes (perhaps from new information/ideas [15]) are the root causes of technological innovation and diffusion at both the micro and macro levels [19]. Indeed, in the field of psychology, where applying the theory of information integration to attitudes and social judgments, [20] reported that "*Integration theory has had reasonable success in the areas of learning, perception, judgment, decision-making, and personality impressions, as well as attitude change*".

Economists have mostly relied on institutional factors to explain technological innovation and catching up [21]. Observing that institutions are created and run by people, which are themselves driven by affective, situational and environmental factors, we adopted a behavioral economics perspective to explore the long-term causes of cross-country heterogeneity in technological capability (ability to innovate and/or adopt new technologies). We achieved this by narrowing our focus on the impact that an information diet, and affective, situational and environmental factors have on GMOs and NPT awareness and expectations in the youth population within the North American Free Trade Area (NAFTA).

As a trilateral free trade agreement between the United States, Canada and Mexico, the NAFTA entered into force in 1994. By 2015, NAFTA had been in place for over 20 years. The adolescent populations in the US, Canada and Mexico in 2015 were born after NAFTA's ratification, and have spent their entire lives under its provisions. As such, they have been directly and indirectly influenced since birth by the technological innovations and diffusion among the three trading partners. This observation therefore raises the following question:

Is there cross-sectional evidence of convergence in youth technological awareness and expectations in relation to the use of gene-editing technology (as biotechnology) and nuclear power technology across the three countries within the bloc?"

To our knowledge, this perspective on convergence has not yet been considered in the literature. Hence, in what follows, we rely on the North American extract of the published youth respondents' data [22] to test the following hypothesis: *Other things being equal, technological innovation and diffusion within NAFTA will, in the long run, lead to the convergence in awareness and expectations of gene editing and nuclear power technologies.*

Our hypothesis is analogous to *the convergence club hypothesis* within the Schumpeterian view of growth, which stipulates that countries can be clustered into clubs, based on structural similarities and steady-state technology and growth convergence [23]. Thus, it further warrants the following research question: *Are the country members within NAFTA of the same technology convergence club in the Shumpeterian view?*

From the perspective of behavioral economics, long-run (steady-states) cross-country convergence in technological awareness and expectations within any trading bloc are expected to be most readily observable amongst youths [20]. This follows due to youths' comparative advantage in learning and adapting to new technological artifacts. Moreover, as suggested by the technology continuance theory [24], and in line with the expectation confirmation model in information technology [25], which is an adaption of the consumer (dis)satisfaction model originally introduced in the field of marketing research as a model of consumer repurchase intention [26], general "awareness and expectations" about technological artifacts, such as GMOs and NPT, has the potential to influence technological (non)acceptance and diffusion [27] and thereby influence cross-country technological (non)convergence [28].

Furthermore, it has been shown that under rationally formed expectations, predicting stages of integration processes to be expected within integrating economies can become self-fulfilling [29]. Therefore, understanding youths' technological attitudes (awareness and expectation), which is defined as *a collection of beliefs, affect, and behavioral intentions towards technological artifacts*, is critical for not only predicting the long-term outcomes of such technologies, but also for providing a scientific basis for informed policy-making to improve member countries' technological capabilities (in terms of long-term innovative ability and absorptive capacity) [30].

Hence, to address our research question, we adopt the following structure for the rest of the paper: In Section 2 we provide a background discussion on gene editing and nuclear power technologies within NAFTA as a free trade area and potential technology convergence club; in Section 3 we present our adopted methodology by first describing the data, followed by the variables used in the analysis, and ending with the econometric model. In Section 4 we present and discuss our findings, while in Section 5 we conclude the analysis.

2. Background

Established in 1992 as one of the key pieces of transnational environmental governance, Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC) prescribes that "*Developed nation members take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other member nations, particularly developing ones*" [31]. Its Clean Development Mechanism (CDM), by providing new and emerging market frameworks, has been credited to greatly stimulate cross-country technological diffusion [32] and thereby help nations such as South Africa benefit from the transfer of nuclear power technology [33].

As the global population grows, the need to increase productivity in the energy and food sectors is being felt by governments, policy-makers, and populations worldwide [34,35]. Innovation in the energy sector is concerned with the set of processes leading to new or improved energy technologies that can augment energy resources, enhance the quality of energy services, and reduce the economic, environmental, or political costs associated with energy supply and use [36]. Because increased energy productivity has positive spillover effects on the productivity of other sectors, including food production [37], energy security is perceived as an important step towards food security [38]. Therefore, in the following subsections, after providing a brief history of the North American free trade agreement, we discuss the use of gene editing and nuclear power technologies in the sustainable production of food and energy, respectively.

2.1. The North American Free Trade Bloc

The North American free trade bloc was formed two years after the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) on 1 January 1994 through a trilateral trade agreement between the USA, Canada, and Mexico [39]. With its environmental cooperation and labor cooperation supplements, the NAFTA partly aimed at carrying first-hand the vision under the UNFCCC. Follow-up studies evaluating its success in achieving its vision reported important achievements in terms of accrued benefits for all three members over the years [40]. Much of the accrued benefits were due to the reduction in import barriers, which spurred trade and investment among the member countries [41]. A 2017 congressional research report [42] concluded that "NAFTA did not cause the huge job losses feared by the critics nor the large economic gains predicted by supporters. However, there were worker and firm costs as the three countries adjusted to more open trade and investment amongst their economies.

Moreover, as trade grew between the three nations, so did innovation, cross-border technological diffusion and patent regulations. Indeed, in their study evaluating NAFTA, [13] reported that it played an important role in stimulating technology transfers among member countries relative to their trade with the rest of the world. However, the extent and scope of technological trade varied by each member country. Mexico, for example, received a large technology inflow (post-NAFTA) but did not contribute much to technology outflows. Canada, on the other hand, observed significant inflows and outflows of technology with NAFTA. In the case of the US, the difference in levels of technology trade with NAFTA members compared to non-NAFTA members was insignificant. Recently, under the leadership of the US, NAFTA country members had come to an agreement to replace its current version with the United States-Mexico-Canada Agreement (USMCA) [43].

Furthermore, as a piece of legislation introduced on 13 December 2019 before the US House of Representatives, the USMCA received the approbation of the US Congress on 19 December 2019 with a bipartisan vote of 385 for, and 41 against. On 16 January 2020 the US Senate voted 89 for and 10 against to clear the bill for the US president's signature to become legislation. The USMCA, which now supersedes NAFTA, is believed to give technology companies additional trading provisions that are new [44]. All signatories have now ratified the agreement—Mexico in June 2019 [38] and Canada on 13 March 2020. The International Trade Commission predicts that the successful implementation of the new trade deal would boost real GDP by $68.2 billion, and create over 176,000 jobs.

2.2. Nuclear Power Technology (NPT)

In the energy sector, nuclear power technology (NPT) has been proposed as a cleaner alternative for achieving energy security [45], which is defined by the International Energy Agency (IAE) as "the uninterrupted availability of energy sources at an affordable price" [46]. Energy security is essential to support basic human needs and economic necessities [47] and represents a critical feature regarding systems planning in the environmental, technical, political and social realm [48].

Data from the US Energy Information Administration and the IAE show that nuclear power has delivered 24,731,525 GWhrs of safe and reliable zero-carbon electricity to the US economy since 1969, and remains an important part of the US energy mix to date [49]. Despite its strategic role in the US economy, nuclear energy remains debated within the domestic context of US energy and climate policy. Some contend that the US should abandon nuclear power energy and commit to a 100% renewable energy future [50], while others contend that current global climate objectives can only be reached if nuclear power is part of the solution, given its high reliability and low carbon footprint [51].

Since the US Atomic Energy Act of 1954, primarily through President Eisenhower's Atoms for Peace program, the US has assumed a global partnership and leadership role in the development and deployment of nuclear power technologies [52]. With climate change-related existential challenges growing, recommendations are being made that US nuclear power policy be re-instituted as an extension of US foreign policy to develop alternative fuels and next-generation advanced nuclear technologies, such as small modular reactors, molten salt reactors and fast reactors, and thorium and high-assay low-enriched uranium (HALEU) [49]. This is in line with the domestic goal of the US of ensuring long-term sustainable energy security, and foreign policy objectives to support economic development in emerging regions with high CO_2 emissions [53].

However, the evidence from nuclear energy transfer to 166 countries suggests that successful diffusion of nuclear power technology depends critically on the structural quality and institutional readiness of receiving nations [54]. The recent installation to support energy demands in remote parts of northern Canada of the Organic Simplified Nuclear Reactor (OSNR) designed by US scientists from Massachusetts Institute of Technology (MIT), as a source for offshore underwater electrical power generation [55], is an example of the innovation and diffusion of nuclear power technology among NAFTA country members.

In Canada, nuclear science and technology contributes over $6 billion annually to the national economy, and also supports many sectors, including medicine, food safety and energy production [37].

In medicine, it is used for the diagnosis and treatment of various diseases, including cancer [56]. In food and safety, gamma rays [57] and Cobalt-60 [58] are widely used to kill bacteria and other pathogens, and also to sterilize much of the industrial food products consumed today.

In the energy sector, nuclear power is the largest non-hydro source of low-carbon, clean energy worldwide [59]. It currently provides 11.5% of the global electricity supply, with 446 operable nuclear reactors worldwide, and a net generating capacity of approximately 391 GWe [37]. NAFTA country members account for 115,104 MWe, with 100, 19, and 2 power reactors currently operating at nuclear generating stations in USA, Canada, and Mexico, for a total net capacity of 100,013 MWe, 13,491 MWe, and 1600 MWe, respectively [60–62]. These capacities represent 19.5%, 16.6%, and 6.8% of the respective shares of electricity production in the USA, Canada, and Mexico.

2.3. Genetically Modified Organisms (GMOs)

In the food sector, gene editing technology (GMOs) has been proposed as a sustainable solution for food security [63,64]. The 1996 World Food Summit declared that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [65]. According to the Cartagena Protocol on Biosafety, a GMO is defined as "any living organism that possesses a novel combination of genetic material obtained using modern biotechnology" [66]. There are two types of GMOs, transgenic and non-transgenic, based on the transformation process [67]. Transgenic GMOs are altered by the addition of genetic material from a different species, while non-transgenic GMOs are genetically modified without the addition of genetic material from any other or the same species [68].

While some countries, like the United States and Canada, grow and consume genetically modified (GM) crops and meat openly [69], others have banned the production and reject their consumption [70]. Within the context of international trade [71], despite demand lags and technological gaps [72], GMO food and agricultural products are now globally available for consumption [73]. Investigation into the global network of GMO technology [74] shows that the top-producing countries of GMOs worldwide (crops and meat) are the United States, Brazil, Argentina, Canada, and India, while Mexico ranks 17th, based on the extent of the area used to grow GM crops [75]. The most commonly produced GM crops are soybean (*Glycine max* L.), maize (*Zea mays subesp. mays* L.), cotton (*Gossypium hirsutum* L.), and canola (*Brassica rapa subsp. oleifera*) [76], with the most frequent traits introduced into the GM species being herbicide tolerance (53%), insect resistance (14%), and a combination of both (33%) [77].

Although there is ample evidence that GMOs improve yield and reliability of the food supply [78,79], their diffusion across the world has been shown to depend on a number of factors, including individual personality traits [80], public trust [81], public perception of specific risks and benefits [82], and national regulatory frameworks [83]. Over time, the information provided through media coverage [84] and scientific publications [85] appear to contribute to growing knowledge [86], trust [87], and better health expectations [88], contributing to increased acceptance.

2.4. Technological Controversies

Using gene editing and nuclear power technologies as solutions to food and energy security remain controversial. Indeed, many aspects of these two technologies, such as their efficacy or safety, are subject to the perspective of diverse social actors [89]. Determining "what they are" and "how good they are" is greatly influenced by society's awareness of and expectations about them [90]. If technologies are bound by the so-called concept of "socio-technical systems" [91,92], then how its people answer these questions plays an important role in both the "construction" and "diffusion" of gene editing and nuclear power technologies in society [93].

For GMOs, different views are held among scientists, producers, consumers, and the general public [94]. Some of the concerns expressed by opponents of GMO use include the potential harm to the environment, biodiversity, and human health [73]. These, in turn, lead to socioeconomic, political, and ethical concerns in society [95,96]. The use of nuclear power technology to reduce carbon emissions, alleviate global warming, and transition to low-carbon societies are considered important by many, including those in the US [50,51]. This is partly because of a series of accidents, including the 1979 three-mile island nuclear incident in Pennsylvania, the 1986 Chernobyl nuclear disaster in Ukraine, and the more recent 2011 Fukushima-Daichii nuclear accident in Japan. The public also associates nuclear energy with risks that include nuclear waste contamination and nuclear weapon proliferation, among others [97].

Beyond all controversies, the creation of the North American Young Generation in Nuclear (NA-YGN), with chapters spanning all three NAFTA country members, and a mission to provide opportunities for the younger generation of nuclear enthusiasts to develop leadership and professional skills and meet the energy challenges of the 21st century [98], is a testament of the important role that young people play in the strategic vision and sustainable development of nuclear power technology within North America [99]. As such, understanding the awareness and expectations of youth about nuclear power technology is indeed of the utmost importance.

3. Methods

The interplay of society and technological artifacts can be studied using different approaches, including the Actor-Network Theory [100], Social Construction of Technology [101], or socio-technical analysis [102]. While the safety and/or efficacy assessments of new technologies necessitate a case-by-case approach, policies are usually implemented with broader intended outreach; therefore, it is convenient to rely on analytical tools that accommodate the potential inter-dependence between gene editing and nuclear power technologies.

To this end, methodologically, we rely on bivariate weighted ordered probit regression modeling [103,104] to represent our two qualitative ordinal measures of youth awareness and expectations about GMOs and NPT in the United States, Canada, and Mexico. This representation allows us to test for the hypothesis of convergence in youth awareness and expectations about the two technologies, in addition to helping us identify the determinant factors of youth technological awareness and expectations within the NAFTA bloc.

3.1. Data Source and Description of the Variables

The data used in this paper were extracted from the published data article [22]. This initially published data contains information on 187,821 students from 50 countries worldwide. After downloading this data set from "Data in Brief", we queried the North American (USA, Canada, and Mexico) subset for use in the present analysis. Additional description of the data sampling design is found in the OECD report ([105], pp. 67–91). The extracted North American subset contains information on 17,981 youth respondents, distributed as 3197 (USA), 4308 (Mexico), 10,476 (Canada), and is presented in Table A1. The exposition in this section closely follows, but also extends the methodological approach presented in [104].

Description of the Dependent Variables

In the present analysis, the dependent variables are adolescent students' levels of awareness and expectations about GMOs and NPT in North America. Figures 1 and 2 summarize the spatial distributions of these variables within NAFTA:

- TA: Self-reported Technological Awareness: ordinal variable assuming the values (1-Never heard, 2-Heard but cannot explain, 3-Know and can provide general explanation 4-Familiar and can provide detailed explanation) for each of the two technologies:
    1. GMOs: TAgmo (mean = 2.55, standard deviation = 0.95);
    2. NPT: TAnpt (mean = 2.61, standard deviation = 0.83);

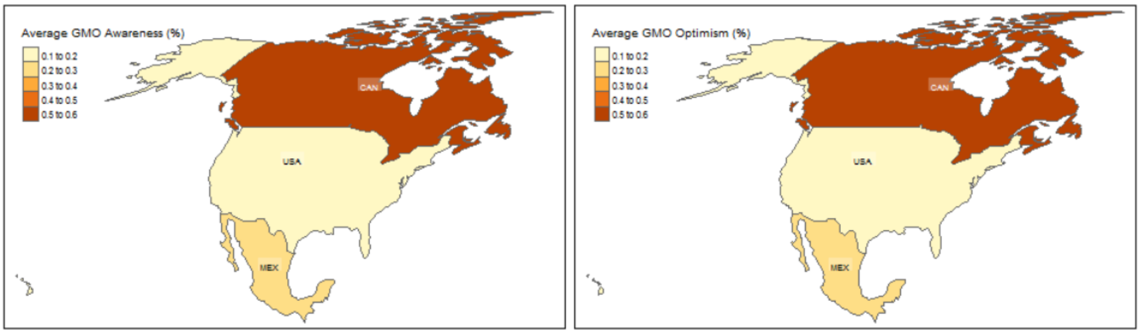

Figure 1. Spatial distribution of youth GMO awareness and expectations within NAFTA.

- TE: Self-reported- Technological Expectation: also an ordinal variable taking the values (1-worse, 2-same, 3-Improve) for each of the two technologies:
    1. GMOs: TEgmo (mean = 2.28, standard deviation = 0.75);
    2. NPT: TEnpt (mean = 2.41, standard deviation = 0.71).

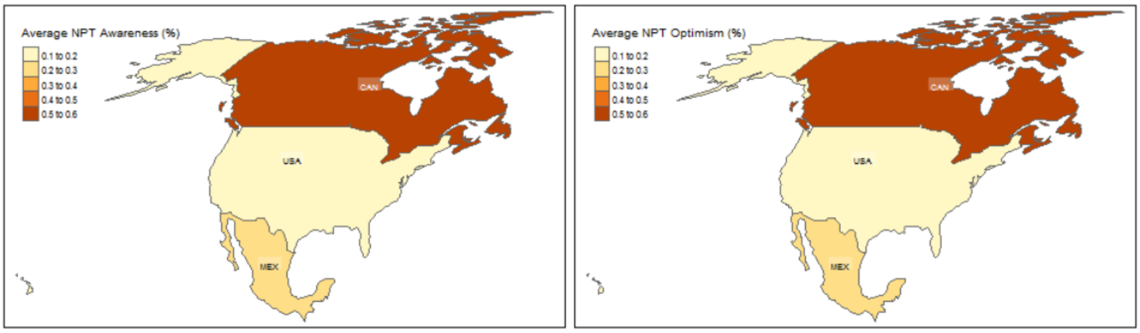

Figure 2. Spatial distribution of youth NPT awareness and expectations within NAFTA.

3.2. Specification of the Econometric Model

Following the seemingly unrelated bivariate weighted ordered probit model of awareness and expectation presented in [103] and subsequently extended in [104], which is derived from the latent variable framework in [106], we assume that the awareness (A^*) and expectation (E^*) of youth respondents i in country j about the technology k are determined by the following two equations:

$$
\begin{aligned}
A^*_{ijk} &= \alpha_{1jk} + \mathbf{x}'_{1i}\beta_{1k} + \epsilon_{1ijk} \\
E^*_{jik} &= \alpha_{2jk} + \mathbf{x}'_{2i}\beta_{2k} + \gamma_k A^*_{ijk} + \epsilon_{2ijk},
\end{aligned}
\tag{1}
$$

where β_{1k} and β_{2k} are estimated vectors of unknown parameters for each technology k, γ_k is the scalar that captures the influence of youths' awareness on their expectations, and is estimated for each technology k. ϵ_{1ijk} and ϵ_{2ijk} represent the residual terms of the awareness and expectation processes, respectively, while α_{1jk} and α_{2jk} represent their respective country-specific effects. The predictor variables in the model system are exogenous with $E(\mathbf{x}'_{1i}\epsilon_{1ijk}) = E(\mathbf{x}'_{2i}\epsilon_{2ijk}) = 0$.

The model expressed in Equation (1) accommodates for any unobserved heterogeneity in youth awareness (A^*_{ijk}) and expectations (E^*_{ijk}) across countries j for each technology k, which are absorbed in the random model intercepts α_{ijk}. These country-specific effects are the sources of variation in youths' GMOs and NPT awareness and expectation within NAFTA which are unaccounted for. Since free trade areas (FTAs) are characterized by trade liberalization and national trade policy autonomy, the country-specific effects control for factors such as the unique local culture, property rights, and regulatory practices in each country, which might help explain observed variations in youths' technological awareness and expectations within NAFTA. By potentially correlating with the included predictors, the country-specific effects could bias their estimated effects if not accounted for appropriately. Our fixed effect estimator implemented here through the Rchoice package [107] allowed us to appropriately identify the model system.

Since the sample space covers youth respondents from all three country members of NAFTA, the above-described approach implies that we would have 3 − 1 = 2 country-specific effects, representing the average differences in GMOs and NPT awareness and expectations between US youth respondents (the reference country), and youth from Canada and Mexico, respectively. These country-specific effects are recovered after estimation using the following equations:

$$\begin{aligned} \hat{\alpha}_{1j} &= \bar{A}^{*}_{ijk} - \bar{\mathbf{x}}_i^{'}\hat{\beta}_{1k} \\ \hat{\alpha}_{2j} &= \bar{E}^{*}_{ijk} - \bar{\mathbf{x}}_i^{'}\hat{\beta}_{2k} - \bar{A}^{*}_{ijk}\hat{\gamma}_k. \end{aligned} \tag{2}$$

3.3. *Test of Convergence in Youth Technological Awareness and Expectations within NAFTA*

We rely on the estimated values of the country-specific effects $\hat{\alpha}_{1j}$ and $\hat{\alpha}_{2j}$ to test for the convergence in youth awareness and expectations about GMOs and NPT technologies within the North American Free Trade bloc. These are composite statistical tests with the following nulls and alternative hypotheses:

3.3.1. Test of Convergence in Youth Technological Awareness

For this composite test, the null hypothesis assumes cross-sectional convergence in youths' GMOs and NPT awareness within the North American free trade bloc as of 2015, which is over 20 years after ratification by the three country members. On the other hand, the alternative hypothesis assumes no cross-sectional convergence in youths' GMOs and NPT awareness within the North American free trade bloc as of 2015. Algebraically, this is equivalent to the following notation:

- $H_0 : \alpha_{1jk} = 0$
- $H_1 : \alpha_{1jk} \neq 0$

For more notational clarity, these composite null and alternative hypotheses can be formulated more explicitly for each of the two technologies, as follows:

(a) For GMO awareness

- $H_0 : \alpha_{1,can,GMO} = \alpha_{1,Mex,GMO} = 0$
- $H_1 : \alpha_{1,can,GMO} \neq \alpha_{1,Mex,GMO} \neq 0$,

where the null explicitly suggests "homogeneity" in youth GMO awareness across the three countries, and hence, cross-sectional convergence in GMO awareness, while the alternative suggests "heterogeneity" in youth GMO awareness, and hence, no cross-sectional convergence. This is similarly so for NPT awareness, as shown next.

(b) For NPT Awareness

- $H_0 : \alpha_{1,can,NPT} = \alpha_{1,Mex,NPT} = 0$
- $H_1 : \alpha_{1,can,NPT} \neq \alpha_{1,Mex,NPT} \neq 0$.

3.3.2. Test of Convergence in Youth Technological Expectations

For this composite test, the null hypothesis assumes cross-sectional convergence in youths' GMO and NPT expectations within the North American free trade bloc as of 2015. On the other hand, the alternative hypothesis assumes no cross-sectional convergence in youths' GMO and NPT expectations within the North American free trade bloc as of 2015. Algebraically, this is equivalent to the following notation:

- $H_0 : \alpha_{2jk} = 0$
- $H_1 : \alpha_{2jk} \neq 0$.

For more notational clarity, these composite null and alternative hypotheses of youth expectations can be formulated more explicitly for each of the two technologies, as follows:

(a) For GMO expectations

- $H_0 : \alpha_{2,can,GMO} = \alpha_{2,Mex,GMO} = 0$
- $H_1 : \alpha_{2,can,GMO} \neq \alpha_{2,Mex,GMO} \neq 0$,

where the null explicitly suggests "homogeneity" in youth GMO expectations across the three countries, and hence, cross-sectional convergence in GMO expectations, while the alternative suggests "heterogeneity" in youth GMO expectations, and hence, no cross-sectional convergence. This is also similar for NPT expectations, as shown next.

(b) For NPT Expectations

- $H_0 : \alpha_{2,can,NPT} = \alpha_{2,Mex,NPT} = 0$
- $H_1 : \alpha_{2,can,NPT} \neq \alpha_{2,Mex,NPT} \neq 0$.

Using the identification method described next, we estimate the effects described in the system of Equation (2), and test the above declined hypotheses.

3.4. Identification of Model Parameters

From the latent variables' model specification in Equation (1), abstracting from the subscripts for country j and technology k, the observed variables for youths' self-expressed technological awareness (TA) and technological expectation (TE) for each technology (GMOs, NPT) are related to their corresponding latent variables in Equation (1), as:

$$TA_i = \begin{cases} 1 - Never\ Heard & \text{if } A_i^* \leq \mu_1 \\ 2 - Heard,\ but\ Unable\ to\ Explain & \text{if } \mu_1 \leq A_i^* \leq \mu_2 \\ 3 - Know,\ can\ provide\ General\ Explanation & \text{if } \mu_2 \leq A_i^* \leq \mu_3 \\ 4 - Familiar,\ can\ provide\ Detailed\ Explanation & \text{if } \mu_3 < A_i^* \end{cases} \quad (3)$$

$$TE_i = \begin{cases} 1 - Worse & \text{if } E_i^* \leq \delta_1 \\ 2 - Same & \text{if } \delta_1 \leq E_i^* \leq \delta_2 \\ 3 - Improve & \text{if } \delta_2 < E_i^* \end{cases} \quad (4)$$

where $\mu_1 < \mu_2 < \mu_3$ and $\delta_1 < \delta_2$ are unknown cutoff points. For identification purposes, following [108,109], we define $\mu_1 = \delta_1 = 0$, while $\mu_0 = \delta_0 = -\infty$ and $\mu_4 = \delta_3 = +\infty$ in order to avoid handling the boundary cases separately. For any two indices j and k on the two latent scales, the probability that $TA_i = j$ and $TE_i = k$ is given by:

$$\begin{aligned} Pr(TA_i = j\,,\ TE_i = k) &= Pr(\mu_{j-1} < A_i^* \leq \mu_j\,,\ \delta_{k-1} < E_i^* \leq \delta_k) \\ &= Pr(A_i^* \leq \mu_j\,,\ E_i^* \leq \delta_k) \\ &- Pr(A_i^* \leq \mu_{j-1}\,,\ E_i^* \leq \delta_k) \\ &- Pr(A_i^* \leq \mu_j\,,\ E_i^* \leq \delta_{k-1}) \\ &+ Pr(A_i^* \leq \mu_{j-1}\,,\ E_i^* \leq \delta_{k-1}). \end{aligned} \quad (5)$$

Assuming the joint distribution of ϵ_{1i} and ϵ_{2i} is bivariate standard normal, with correlation ρ, each youth's contribution to the likelihood function is expressed as:

$$\begin{aligned} Pr(TA_i = j\ ,\ TE_i = k) = {} & \Phi_2(\mu_j - \alpha_j - \mathbf{x}'_{1i}\beta_1\ ,\ (\delta_k - \alpha_k - \gamma\mathbf{x}'_{1i}\beta_1 - \mathbf{x}'_{2i}\beta_2)\zeta, \tilde{\rho}) \\ & - \Phi_2(\mu_{j-1} - \alpha_{j-1} - \mathbf{x}'_{1i}\beta_1\ ,\ (\delta_k - \alpha_k - \gamma\mathbf{x}'_{1i}\beta_1 - \mathbf{x}'_{2i}\beta_2)\zeta, \tilde{\rho}) \\ & - \Phi_2(\mu_j - \alpha_j - \mathbf{x}'_{1i}\beta_1\ ,\ (\delta_{k-1} - \alpha_{k-1} - \gamma\mathbf{x}'_{1i}\beta_1 - \mathbf{x}'_{2i}\beta_2)\zeta, \tilde{\rho}) \\ & + \Phi_2(\mu_{j-1} - \alpha_{j-1} - \mathbf{x}'_{1i}\beta_1\ ,\ (\delta_{k-1} - \alpha_{k-1} - \gamma\mathbf{x}'_{1i}\beta_1 - \mathbf{x}'_{2i}\beta_2)\zeta, \tilde{\rho}), \end{aligned} \quad (6)$$

where $\zeta = \frac{1}{\sqrt{1+2\gamma\rho+\gamma^2}}$ and $\tilde{\rho} = \zeta(\gamma + \rho)$. Φ_2 is the cumulative distribution function of the bivariate standard normal. This model specification is referred to as simultaneous bivariate ordered probit, which simplifies to a seemingly unrelated specification (with $\zeta = 1$ and $\tilde{\rho} = \gamma$) when $\rho = 0$. As in [103,104], the model is estimated here under the weighted seemingly unrelated specification, using the package [107] from the R statistical software [110].

4. Results

4.1. Descriptive Summary Statistics of the Explanatory Variables

The means and standard deviations of the quantitative variables at the top of Table A1 show that the average youth respondent is somewhat interested (3.50) in ecosystem services and sustainability, but more interested (4.02) in how science can help prevent diseases. The standardized measure of youth enjoyment of science suggests that the average adolescent in the North American free trade bloc is 0.44 standard deviations above the mean value of youths' science enjoyment across all respondents in the 2015 Programme for International Students Assessment (PISA) [111].

With regard to youths' information diet, which may help shape their awareness and expectations about GMOs and NPT within NAFTA, it can be noted that the average adolescent reports to regularly visit ecological websites (3.41), follow news blogs (3.27), read books on broad science (3.37), visit websites on broad science (3.06), read science articles in magazines and newspapers, and also attend science clubs (3.70). Of all the sources of information considered, television programs on broad science, which respondents report to watching sometimes (2.95), seem to attract the least interest of youths.

The descriptive results from the socio-economic and demographic factors suggest that the average youth respondent is 15.84 years of age, and lives in a family with wealth that is 0.14 standard deviations above the mean value of wealth across all respondents, and has a socio-economic status that is 0.13 standard deviations above the mean economic, social, and cultural status across all respondents. Furthermore, the mean parental education level shows that both parents (mother (4.50) and father (4.38)) have at least a post-secondary non-tertiary education, based on the UNESCO international standard classification of education.

The descriptive results of the qualitative variables at the bottom of Table A1 suggest that the majority of the youth respondents in our sample live in Canada (58.26%), followed by Mexico (23.96%), and finally, USA (17.78%). Most respondents (83.27%) are natives of their country of reporting, with only 7.70% first-generation immigrants, and 9.03% second-generation. With respect to gender, we note that 52.38% of the respondents are females, against 47.62% males. In terms of their grade in school, we note that most youths (83.3%) are in 10th grade, followed by 12.02% in 9th grade, then 3.65% in 11th grade, 0.67% in 8th grade, 0.27% in 7th grade, and finally, 0.08% in 12th grade. This latter result suggests that 98.97% of all youth respondents in the data are between 9th and 11th grade.

4.2. Unconditional Frequency Distributions of Youth Technological Awareness and Expectations

Table A2, and Figure 3 summarize the unconditional percent relative frequency distributions of youth awareness and expectations about GMOs and NPT within the North American free trade bloc. With regard to GMO awareness (TAgmo), we note that the majority of youth (34.78%) report to having heard about GMOs but are unable to explain, followed by 32.66% that report knowing about it and able to provide general explanations, then 18.31% that report being familiar with GMOs and able to provide detailed explanations, and finally, 14.25% that report having never heard about GMOs.

Concerning youth GMO expectations for the next 20 years (TEgmo), we note that the majority of youth respondents are optimistic (46.38%), and believe it will improve over time, followed by 35.6% that believe it will stay the same, and finally, 18.02% that feel pessimistic, believing it will get worse over the next 20 years.

We also observe a similar pattern with regard to youth NPT awareness and expectations. Indeed, from the distribution of youth NPT awareness (TAnpt) we note that the majority of North American youth adolescents (38.86%) report to having heard about NPT, but are unable to explain, followed by 38.32% that report knowing about it and being able to provide general explanations, then 15.33% that report being familiar with it and able to provide detailed explanations, and finally, 7.49% that report having never heard about it. In relation to their expectations about NPT for the next 20 years (TEnpt), we note that the majority of youth respondents are optimistic (54.28%), and believe it will improve overtime; followed by 32.24% that trust it will stay the same, and finally, 13.48% that feel pessimistic, trusting it will get worse over the next 20 years.

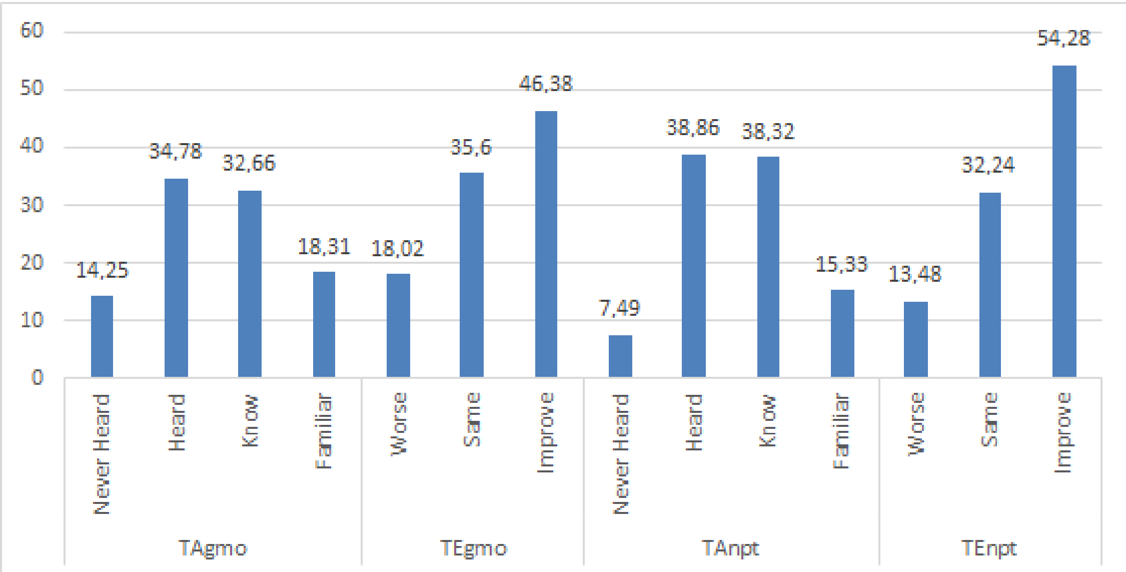

Figure 3. Unconditional percent relative frequencies of youth technological awareness and expectations.

4.3. Conditional Frequency Distributions of Youths' Technological Awareness and Expectations

Disaggregating the above-described unconditional percent relative frequency distributions by youth country of residency (CNT) within NAFTA, we can observe the variations in youths' awareness and expectations about GMOs and NPT across the North American Free Trade bloc. This conditional percent relative frequency distribution is presented in Table A2, and further summarized in Figure 4.

Focusing on GMO awareness (TAgmo), we note that except among the youth that report to being familiar with GMOs and able to provide detailed explanations, where the relative frequency of youth from USA (17.89%) is higher than that of Mexico (8.72%) and both lower than that of Canada (74.06%), across all levels of GMO awareness, the relative frequency of youth is the highest in Canada, followed by Mexico, and finally, the USA. With regard to GMO expectations (TEgmo), we note that overall, across all levels of expectations, the relative frequency of youth is the highest in Canada, followed by Mexico, then the USA.

Turning our attention now to youth awareness about NPT (TAnpt), we observe an identical pattern to that previously described for the case of GMO awareness (TAgmo). The same observation is made of youth expectations about NPT (TEgmo), also in Figure 4.

In sum, the results indicate significant variations in youths' GMOs and NPT awareness and expectations between USA, Canada, and Mexico. The chi-square test results in the last column of Table A2 further confirm these results. Since the p-values of the chi-square tests are less than ($\alpha = 0.1\%$), we have significant dependent relationships between youths' countries of residence (CNT) within NAFTA, and their reported technological awareness (TAgmo, TAnpt) and expectations (TEgmo, TEnpt).

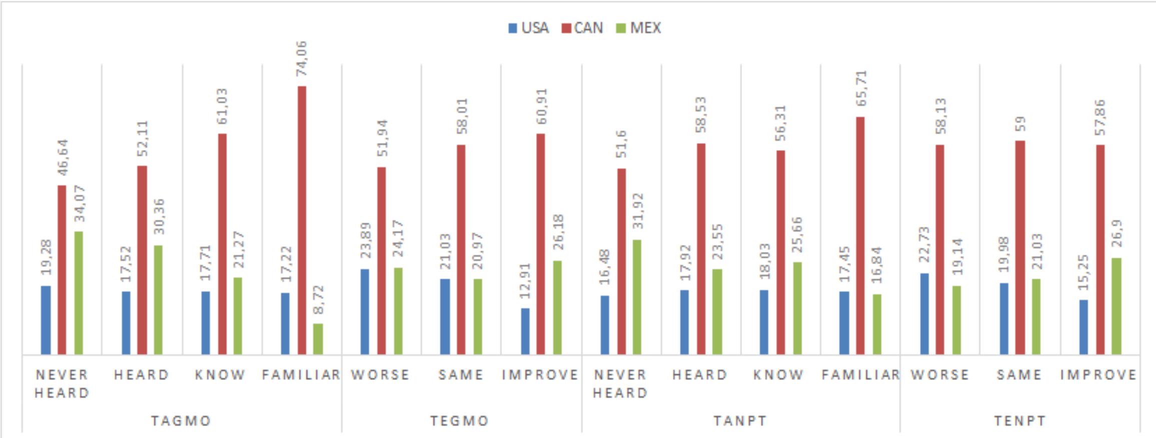

Figure 4. Conditional percent relative frequencies of youth technological awareness and expectations by country.

4.4. Econometric Results

The determinant factors of youths' GMOs and NPT awareness and expectations have been grouped into four broad categories, including: Affective factors, knowledge control factors, demographic & economic factors, and country-specific factors. Tables A3 and A4 summarize these results for GMOs and NPT, respectively.

4.4.1. Determinants of Youths' GMO Awareness within NAFTA

Maximum likelihood estimation (MLE) results for the determinants of youths' GMO awareness are summarized in the first column of Table A3. Starting with the affective factors, we note that all three have positive and significant effects on youth awareness about GMOs in the North American free trade area. Indeed, each level of increase in youths' interests in ecosystem services and sustainability (IntBiosph) raises their level of awareness about GMOs by 16.6%. Similarly, each level of increase in youths' interest in science as a means for disease prevention (IntScPrevDis) raises their awareness about GMOs by 3.9%. Moreover, a standard deviation increase in youths' normalized index of science enjoyment also increases their awareness about GMOs by 17.3%.

Conversely, the knowledge control factors (information diet) all have negative and significant effects, suggesting that each level of increase in youths' frequency of ecological website visits (EcoWebVisit), blog visits (BlogsVisit), broad science television program watching (BroadScTVprog), broad science book reading (BroadScBooks), broad science web browsing (BroadScWeb), science article reading in newspapers and magazines (MagScArtNewsp), and science club attendance (ScClubAttend) reduce by 0.5%, 6%, 3.2%, 2.4%, 5%, 2.5%, and 2.1% in youths' awareness about GMOs, respectively.

From the demographic and economic factors, we note that each year of increase in age raises youths' awareness by 6.7%, while each unit increase in family wealth raises their GMO awareness by 0.6%. Moreover, each standard deviation increase in youths' standardized index of economic, social, and cultural status (ESCS) leads to 16% higher awareness about GMOs. Furthermore, each level of increase in father's education raises by 2.1% youths' GMO awareness, while each level of increase in mother's education reduces youths' GMO awareness by 6.7%.

The positive coefficient value on the gender variable suggests that compared to female respondents, males are 8.9% more aware about GMOs. The estimated effects of immigration status suggest that, compared to youth who are natives of their country of reporting, first-generation immigrants youth do not show a significant difference in GMO awareness, while second-generation youth immigrants do show 6.7% less awareness about GMOs. Finally, the grade level effects show that compared to youth in

7th grade, those in 8th and 11th grade are 4.6% and 3.8% more aware about GMOs, respectively, while those in grades 9, 10, and 12 are 17.3%, 8.8%, and 64.8% less aware about GMOs, respectively.

4.4.2. Determinants of Youths' GMO Expectations within NAFTA

MLE results for the determinants of youths' GMO expectations are summarized in the second column of Table A3. All three affective factors are found to positively and significantly affect youth expectations about GMOs in the North American free trade area. Indeed, we note that each level of increase in youths' interest in ecosystem services and sustainability (IntBiosph) raises their level of optimism about GMOs by 2.2%. This is similar for each level of increase in youths' interests in science as a means for disease prevention (IntScPrevDis), which is found to raise youth optimism about GMOs by 1.9%. Finally, each standard deviation increase in youths' normalized index of science enjoyment positively influences (0.5%) their expectations about the evolution of GMOs for the next 20 years in the North American free trade area.

Turning our attention to the knowledge control factors (information diet), we note that all sources of information positively affect youths' GMO expectations, except for broad science television program viewing, which seems to negatively influence youths' expectations. Indeed, the results show that each level of increase in youths' frequency of ecological website visits raises their optimism about GMOs by 3.7%; however, this figure is 1.5% for increased frequency of blog visits by youth, 0.4% for their increased frequency of broad science book reading, 0.5% for their increased frequency of broad science web browsing, 1.7% for their increased frequency of science article reading in newspapers and magazines, and finally, 2.9% for youths' increased frequency of science club attendance. On the contrary, each level of increase in youths' frequency of broad science television program viewing reduces their level of optimism about GMOs in the North American free trade area by 0.8%.

From the demographic and economic factors, we note that each year of increase in age raises youths' optimism about GMOs by 0.7%, while each unit increase in family wealth reduces their optimism about GMOs by 4.3%. Moreover, each standard deviation increase in youths' standardized indices of economic, social, and cultural status (ESCS), raises their optimism about GMOs by 8.8%. However, conversely, each level of increase in parental education reduces youth optimism about GMOs by 0.6% for their mother's education, and 1.6% for the father's education, respectively.

The negative coefficient value on the gender variable suggests that, compared to female youth respondents, males are 17.1% less optimistic about GMOs. The estimated effects of immigration status suggest that compared to youth who are natives of their country of reporting, first- and second-generation immigrant youth are 12% and 9.2% less optimistic about GMOs in the North American free trade area, respectively.

The estimated grade level effects show that compared to their 7th grade counterparts, youth in 8th, 9th, 10th, 11th, and 12th grades are 10.9%, 19%, 27.4%, 39.5%, and 70% more optimistic about the evolution of GMOs for the next 20 years in the North American free trade area, respectively. Finally, the positive coefficient value ($\hat{\gamma} = 0.025$) on the awareness variable at the bottom of Table A3 indicates that youth in the North American free trade area are 2.5% more optimistic about GMOs for every level of increase in their awareness about genetically modified organisms.

4.4.3. Determinants of Youths' NPT Awareness within NAFTA

MLE results for the determinants of youths' NPT awareness are summarized in the first column of Table A4. Starting with the affective factors, all three have positive and significant effects on youth awareness about NPT in the North American free trade area. Indeed, it can be noted that each level of increase in youths' interests in ecosystem services and sustainability (IntBiosph) raises their level of awareness about NPT by 14.6%. This is similar for every level of increase in youths' interest in science as a means for disease prevention (IntScPrevDis), which is found to raise youths' NPT awareness by 4.8%. Finally, each standard deviation increase in youths' normalized index of science enjoyment also raises their awareness about NPT by 13.8%.

Conversely, the knowledge control factors are all negative and significant, except for "ScClubAttend", suggesting that each level of increase in youths' frequency of ecological website visits (EcoWebVisit), blog visits (BlogsVisit), broad science television program watching (BroadScTVprog), broad science book reading (BroadScBooks), broad science web browsing (BroadScWeb), and science article reading in newspapers and magazines (MagScArtNewsp) reduces their awareness about NPT by 4.2%, 7.1%, 3.2%, 3.3%, 3.8%, and 3.9%, respectively. Conversely, each level of increase in science club attendance (ScClubAttend) raises youths' awareness about NPT in the North American free trade area by 3.5%.

From the demographic and economic factors, we note that each year of increase in age raises youths' awareness about NPT by 3.2%, while each unit increase in family wealth raises youths' awareness about NPT by 2.1%. Moreover, each standard deviation increase in youths' standardized index of economic, social, and cultural status (ESCS) leads to 5.8% higher awareness about NPT. Furthermore, each level of increase in the father's education level raises youths' NPT awareness by 2.3%. Conversely, each level of increase in the mother's education level was found to reduce youths' NPT awareness by 1.9%.

The positive coefficient value on the gender variable suggests that, compared to female respondents, males are 15% more aware about NPT. The estimated coefficient values on immigration status suggest that, compared to youth who are natives of their country of reporting, first-generation immigrants youth are 5.4% more aware about NPT, while second-generation youth immigrants show 12.9% less awareness about NPT in the North American free trade area.

Finally, the effects of grade levels suggest that compared to youths in 7th grade, only those in 8th, 11th, and 12th grades show significantly different levels of awareness about NPT. However, although 8th graders relatively show 8.4% less awareness, 11th and 12th graders show 11.5% and 61.5% more awareness about NPT in the North American free trade area, respectively.

4.4.4. Determinants of Youths' NPT Expectations within NAFTA

MLE results for the determinants of youths' NPT expectations are summarized in the second column of Table A4. Focusing first on the affective factors, we note that each level of increase in youths' interests in ecosystem services and sustainability (IntBiosph) raises their level of optimism about NPT by 1%. A similar observation is made for each level of increase in youths' interests in science as a means for disease prevention (IntScPrevDis), which is found to raise their optimism about NPT by 2.8%. Conversely, each standard deviation increase in youths' normalized index of science enjoyment reduces their expectations about the evolution of NPT in the next 20 years by 1.5%.

Turning our attention now to the knowledge control factors (information diet), we note that all sources of information positively affect youth NPT expectations, except for blog visits (BlogsVisit) and broad science web browsing (BroadScWeb), which seem to negatively influence youths' expectations. Indeed, the results show that each level of increase in youths' frequency of ecological website visits raises their optimism about NPT by 6.4%; this figure is, however, 2.7% for youths' increased frequency of broad science television program viewing, 0.45% for their increased frequency of broad science book reading, 1% for their increased frequency of science article reading in newspapers and magazines, and finally, 6.4% for youths' increased frequency of science club attendance. On the contrary, North American youth are 1.3% less optimistic about NPT for each level of increase in their frequency of news blog visits (BlogsVisit), while they are 2.1% less optimistic about the technology for each level of increase in their frequency of broad science web browsing (BroadScWeb).

From the demographic and economic factors, we note that each year of increase in age raises youths' optimism by 4.5%, while each unit increase in family wealth reduces youth optimism about NPT by 1.4%. Furthermore, each standard deviation increase in the standardized index of economic, social, and cultural status (ESCS) raises youths' optimism about NPT by 6.2%. Conversely, however, each level of increase in parental education reduces youths' optimism about NPT by 0.4% for their mother's education, and 1% for their father's education, respectively. The estimated effects of immigration status suggest that, compared to youth who are natives of their country of reporting, first-generation immigrant youth are 3.4% more optimistic, while second-generation immigrant youth are 2.7% less optimistic about NPT.

The estimated grade level effects show that, compared to their 7th grade counterparts, youths in 8th, 9th, 10th, and 11th grades are 3.4%, 23.8%, 46.3%, 63.1%, and 68.8% more optimistic about NPT, respectively. Finally, the positive coefficient value ($\hat{\gamma}$ = 0.067) for awareness at the bottom of Table A4 indicates that youth in the North American free trade area are 6.7% more optimistic about NPT, for each level of increase in their awareness of the technology.

4.5. Convergence Test Results

The results of the tests of convergence in youths' technological awareness and expectations within the North American free trade bloc are captured by the estimated country-specific effects reported at the bottom of Tables A3 and A4 for GMOs and NPT, respectively.

4.5.1. Convergence in Youth GMOs and NPT Awareness within NAFTA

For the test of convergence in youths' GMO awareness, as stated in Section 3.3.1 (a), since the country-specific effects at the bottom of the first column in Table A3 are all statistically significant, we reject the null hypothesis and conclude that the evidence is enough to suggest the existence of significant heterogeneity in youths' awareness about GMOs between USA, Canada, and Mexico. More specifically, compared to youth from the USA, those from Canada show 15.2% more awareness about GMOs, while youth from Mexico are 34.4% less aware about GMOs than their USA counterparts. Together, these results indicate the absence of convergence in youths' GMO awareness within the North American Free trade bloc.

A similar observation is made about the test of convergence in youths' NPT awareness, as stated in Section 3.3.1 (b). Indeed, since the country-specific effects at the bottom of the first column in Table A4 are all statistically significant, we reject the null hypothesis and conclude that the evidence is enough to suggest the existence of significant heterogeneity in youths' awareness about NPT between USA, Canada, and Mexico. More specifically, compared to youth from the USA, those from Canada are 7.1% more aware about NPT, while youth from Mexico are 19.5% less aware about NPT than their USA counterparts. Together, these results suggest the absence of convergence in youths' awareness about NPT within the North American Free trade bloc.

4.5.2. Convergence in Youth GMO and NPT Expectations within NAFTA

With regard to the test of convergence in youths' expectations about GMOs as stated in Section 3.3.2 (a), since the country-specific effects at the bottom of the second column in Table A3 are all positive and statistically significant, we reject the null hypothesis, and conclude that the evidence is enough to suggest the existence of significant heterogeneity in youths' expectations about GMOs between USA, Canada, and Mexico. More specifically, compared to youth from the USA, those from both Canada and Mexico are 34.4% and 39.9% more optimistic about the evolution of GMOs in the next 20 years, respectively. Together, these results indicate the absence of convergence in youths' expectations about GMOs within the North American Free trade bloc.

A similar observation is made about the test of convergence in youths' expectations about NPT, as stated in Section 3.3.2 (b). Indeed, since the country-specific effects at the bottom of the second column in Table A4 are all positive and statistically significant, we reject the null hypothesis, and conclude that the evidence is enough to suggest the existence of significant heterogeneity in youths' expectations about NPT between USA, Canada, and Mexico. More specifically, compared to youth from the USA, those from both Canada and Mexico are 15% and 49.7% more optimistic about the evolution of NPT in the next 20 years, respectively. Together, these results suggest also the absence of convergence in youths' expectations about NPT within the North American Free trade bloc.

5. Discussion

Despite the richness of the convergence literature, including ([112], p. 311) which states that "*convergence research has brought to fore the importance of technological differences across countries and has led to the development of new methodologies for quantification of these differences. The results of these quantification efforts are providing a new information base for examining alternative models of technology generation and diffusion. This information base is also helpful for understanding the interaction among countries along other dimensions such as trade, migration, spread of institutions...*", the present study is the first to look at convergence within the context of youth awareness and expectations about specific technological artifacts. Indeed, despite the fact that modern biotechnology (GMOs) and nuclear power technology are two of the most transformative technologies of the 21st century [101], very little is still known about youth awareness and expectations about these technologies, let alone their diffusion between trading partners. Our present analysis is, therefore, a step in that direction.

The heterogeneity of youth awareness and expectations about GMOs and NPT and the lack of convergence within NAFTA that we found suggest that the three countries are not members of the same technology convergence club in the Schumpeterian view. Instead, we find support for the presence of country-specific regimes in conditional convergence [113]. Empirically, the distinction between "club convergence" and "conditional convergence" is not always clear. The idea of club convergence is based on models that yield multiple equilibria for a group of economies that may differ fundamentally in their initial structures. Economies with a similar initial structure, approach a common steady-state equilibrium in the long run. In conditional convergence, equilibrium depends on the structural features of an economy; each particular nation approaches its own and unique equilibrium ([112], p. 315). Therefore, within the conditional convergence framework, nations with initially different technological endowments are expected to converge to different steady-state levels of technology and per-capita labor productivity, even with technological diffusion.

The Clean Development Mechanism (CDM) of the UNFCCC laid the ground to stimulate cross-country technological diffusion about 2 years prior to the ratification of NAFTA [32]. However, when NAFTA was being signed in 1994, there were major structural differences between the Mexican economy and its North American counterparts [40]. These included differences in initial technological endowment, human capital endowment, and labor productivity [4]. It would follow that initial technological awareness and expectations, which depend upon initial human capital endowment and technological capability, would also differ among them. Therefore, as suggested by conditional convergence [113], we expect initial differences in technological awareness and expectations across the three economies to evolve into steady-state differences, even with technological innovation and diffusion among them [12], due to common membership in NAFTA. Moreover, technological awareness and expectation at any given point in time drives contemporaneous commitments and resource allocation, the latter of which helps drive innovation. Cross-country differences in the ability to innovate at any given point in time would naturally translate into differences in actual innovation. In the absence of a perfectly frictionless world, differences in innovation, even with diffusion, could not reasonably lead to homogeneity in technological endowment, awareness, and expectations.

Our finding that increased parental education (both mother's and father's) unilaterally reduces youths' optimism about both GMOs and NPT means that children of more highly educated parents are less favorably disposed to see gene editing and nuclear power technologies as desirable means to food and energy security. Parental attitudes toward these technologies appear to influence their children's in the same direction. This conjecture receives theoretical support from the "expectancy-value theory (EVT)" in the field of developmental and educational psychology [114,115]. According to EVT, children and adolescents' achievement-related choices and career aspirations and choices are most directly influenced psychologically by ability, perceived competence, and the subjective task value attached to the various options available to them. By influencing youths' opportunities to engage in activities through educational experiences, parents and special programs have the ability to shape their perceptions and views [116].

In conformity with the importance of the fourth helix in the quadruple helix model of innovation [117], the development and diffusion of gene editing and nuclear power technologies in democratic societies, such as those in NAFTA, is highly dependent upon the public's perception and acceptance of such technologies. If the levels of awareness and optimism we observed in the youth population were to remain, then they will eventually manifest into subsequent investments and adoptions of the two technologies; however, this outcome will be reversed if observed unfavorable parental attitudes were to be dominant in the long run. As evidenced by [118], open innovation strategies under a quadruple helix model of innovation in the gene editing and nuclear power sectors within NAFTA might prove to be useful. Indeed, in other instances, scholars have shown the value of leveraging the collective intelligence of open innovation to tackle complex social and technical problems [119,120]. The "Challenge.gov" program in the US is an example of such initiatives intended to encourage active participation in the public sector by drawing ideas and information from interested citizens [121]. In our current regional context, this might take the form of a crowd-sourced science club, allowing participation of citizens from all three countries.

We also find that increased parental education has a divergent effect on youth awareness about the two technologies, depending on the gender of the parent. While greater levels of paternal education raise youths' reported level of awareness about gene editing and nuclear power technologies, higher maternal education reduces youths' reported level of awareness about the two technologies. Gender-based differences also appear in other areas, such as occupational preferences, lifestyle values, and field-specific ability beliefs between men and women. One consequence may be that men are found to be more inclined to specialize in science, technology, engineering, and mathematics (STEM) than women [122]. These types of gender-based differences in STEM interests and careers at the parental level may provide men with relatively more exposure, and perhaps more knowledge about the two (gene editing and nuclear power) technologies than women, thereby allowing men to have a relatively more positive influence on their children's awareness than their female counterparts. This conjecture finds validation in (pre-2015) studies in the context of the US, which reported that despite impressive gains by females in recent years, concerns still remained in fewer females pursuing degrees and careers in certain STEM fields [116]. This study was later updated in 2017 by [123], who continue to observe significant disparities in computer science, engineering, and physics, despite the accrued gender balance in fields such as biology, chemistry, and mathematics [124].

The estimated effects of youths' own gender on their awareness about the two technologies corroborate the findings above on the influence of parental education. Indeed, compared to their female counterparts, male youth are consistently found to be more aware about both gene editing and nuclear power technologies. This suggests that past gender-based specialization differences in STEM-related fields are still operating at the societal level among children. Our results are further in line with the evidence from [124], which shows that gender differences in STEM career choices as a reflection of differences in interests reach as far back as early adolescence and are subsequently reinforced through lifelong decision-making, experiential outcomes, and the expectations of others.

Nevertheless, the fact that youth involvement in science clubs (ScClubAttend) is successful in both raising their awareness, while also promoting positive expectations about the future of nuclear power technology provides hope for the long-term survival of the technology. This result highlights the importance of organizations like the NA-YGN [98], which provides an opportunity for young nuclear enthusiasts to develop the leadership and professional skills required to move the North American nuclear power industry forward. It is also consistent with the Theory of Planned Behavior (TPB) and community resilience, which reports awareness of local clean energy initiatives, risk perceptions, environmental messaging, and environmental orientation to influence young millennial attitudes toward federal clean energy policy and taxes in the United States [125]. Perhaps concerned microbiologists and food scientists can organize an analog to the NA-YGN for the biotechnology sector, such as a "Foundation for Biotechnology Awareness and Education", as a way of bringing young people to the table for the future of the North American biotechnology sector.

Finally, given the non-convergence of awareness and expectations observed in our data, the path to convergent technological progress through open innovation, as articulated by [126], does not seem immanent for these two technologies within NAFTA. Various national-level studies elsewhere show promising technological convergence from open innovation in industries such as foods and pharmaceuticals [127,128], mobile telecommunication [129], and textile machinery [130]; this ideal in our current regional context will require deeper and wider knowledge of gene editing and nuclear power technologies by the youth in the region. Whether diffusion of this knowledge among NAFTA-USMCA can be leveraged by the kinds of convergence that [126,131] note, remains a hope for further advancements of these two important technologies.

6. Conclusions

This study used a cross-sectional sample of youth respondent data from the United States, Canada, and Mexico, along with seemingly unrelated bivariate weighted ordered probit regression modeling [104] to analyze the impact of affective, cognitive, situational, socio-economic and demographic factors, and information diets on North American youths' awareness and expectations about both gene editing technology (GMOs) and nuclear power technology (NPT). Then, following the Schumpeterian tradition, which perceives technological innovation and diffusion as the major enabler of growth and catching up, the study tested the club convergence hypothesis within NAFTA.

The heterogeneity and non-convergence in youth awareness and expectation about GMOs and NPT found in our study leads us to reject the hypothesis that NAFTA is a technology convergence club in the Schumpeterian view, while supporting the existence of differing growth regimes among the three countries within the bloc. Overall, we found higher youth awareness in Canada and less in Mexico relative to the US. We also found that Canada's and Mexico's youth had more positive expectations about the futures of these technologies. The absence of club convergence suggests that these differences could persist despite operating in a FTA. Higher levels of youth awareness and expectations may not be desirable if the science behind educational programs is flawed or if awareness and expectations are fueled by agendas of rent seekers who benefit from misinformation. However, we are of the general opinion that good ideas tend to displace bad ones, and so innovation are desirable in the long-run. If correct, then it is important for policy makers to continue to invest in basic and applied research and to develop and implement educational programs that support this end. We found evidence that science clubs bring more awareness about these technologies in the youth population. As optimists about the future of mankind, it is our view that pressing problems with energy and food production will eventually be "solved" by developments in science and technology. For countries to thrive as resources become increasingly scarce, our future will rely on today's well-informed and educated youths to make it happen. Our results suggest that there is more important work to be done in promoting awareness of and developing realistic expectations for our future. Given the cross-sectional nature of our study, prospective investigations relying on panel data could provide additional insights into the temporal dynamics of youth technological awareness and expectations.

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Appendix A

Table A1. Summary Description of the Variables used in the Econometric Modeling (N = 17,981).

Quantitative Variables	(Means and Standard Deviations)	Mean	s.d.
IntBiosph	Level of interest in Ecosystem services and Sustainability 1-Don't know what it is, 2-not interested, 3-Hardly interested, 4-Interested, 5-highly interested.	3.50	0.98
IntScPrevDis	Level of Interest in how science can help prevent disease; 1-Don't know what it is, 2-not interested, 3-Hardly interested, 4-Interested, 5-highly interested;	4.02	1.03
JOYSCIE	PISA index of student's Enjoyment of science	0.44	1.07
	How often student do the following: 1-never or Hardly, 2-sometimes, 3-regularly, 4-very often.		
EcoWebVisit	↪ Visit Ecological Websites:	3.41	0.82
BlogsVisit	↪ Follow news via blogs:	3.27	0.91
BroadScTVprog	↪ Watch TV programs on broad science:	2.95	0.88
BroadScBooks	↪ Read books on broad science:	3.37	0.80
BroadScWeb	↪ Visit websites on broad science:	3.06	0.91
MagScArtNewsp	↪ Read science article in magazine and newspaper:	3.24	0.86
ScClubAttend	↪ Attend science club:	3.70	0.66
AGE	Student's age	15.84	0.29
WEALTH	Student's family wealth index value	0.14	1.34
ESCS	Standardized Index of economic, social and cultural status	0.13	1.14
MISCED	Student's Mother Education level	4.50	1.66
FISCED	Student's Father Education level	4.38	1.65
WFSTUWT	Student final weight in the Data	161.61	240.95
Qualitative Variables	**(absolute and percent relative frequencies)**	**Abs. Freq.**	**Rel. Freq.**
Gender	Gender:		
	1-Female	9419	52.38
	2-Male	8562	47.62
IMMIG	Student Immigration status:		
	1-Native	14,973	83.27
	2-Second-generation	1623	9.03
	3-First-generation	1385	7.70
GradeLev	Student grade level in school:		
	7th grade	49	0.27
	8th grade	121	0.67
	9th grade	2161	12.02
	10th grade	14,979	83.30
	11th grade	657	3.65
	12th grade	14	0.08
CNT	Unique Identifier for each NAFTA country member		
	1-USA	3197	17.78
	2-Canada	10,476	58.26
	3-Mexico	4308	23.96

Source: Authors' construction using the NAFTA extract of the published data [22].

Table A2. Conditional and Relative Frequencies of Youth Technological Awareness and Expectation.

		CNT USA	CNT CAN	CNT MEX	Rel. Freq. (%)	Chi^2 Test
TAgmo	1	19.28	46.64	34.07	14.25	X-squared = 806.2 ***
	2	17.52	52.11	30.36	34.78	df = 6, p-value $< 2.2 \times 10^{-16}$
	3	17.71	61.03	21.27	32.66	
	4	17.22	74.06	8.72	18.31	
TEgmo	1	23.89	51.94	24.17	18.02	X-squared = 290.47 ***
	2	21.03	58.01	20.97	35.60	df = 4, p-value $< 2.2 \times 10^{-16}$
	3	12.91	60.91	26.18	46.38	
TAnpt	1	16.48	51.60	31.92	7.49	X-squared = 145.67 ***
	2	17.92	58.53	23.55	38.86	df = 6, p-value $< 2.2 \times 10^{-16}$
	3	18.03	56.31	25.66	38.32	
	4	17.45	65.71	16.84	15.33	
TEnpt	1	22.73	58.13	19.14	13.48	X-squared = 164.6 ***
	2	19.98	59.00	21.03	32.24	df = 4, p-value $< 2.2 \times 10^{-16}$
	3	15.25	57.86	26.90	54.28	
Rel. Freq.	(%)	17.78	58.26	23.96		

Source: Author's construction using the NAFTA extract of the published data [22]; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A3. MLE Results for Youth's GMO awareness and Expectations within NAFTA.

N 17,981	Awareness Coef.	(s.e.)	Expectations Coef.	(s.e.)
Cutoff 2	$\hat{\mu}_2 = 1.157$ ***	(0.001)	$\hat{\delta}_2 = 1.057$ ***	(0.001)
Cutoff 3	$\hat{\mu}_3 = 2.227$ ***	(0.001)		
(Intercept)	0.145 ***	(0.042)	−0.075	(0.044)
Affective factors				
IntBiosph	0.166 ***	(0.001)	0.022 ***	(0.001)
IntScPrevDis	0.039 ***	(0.001)	0.019 ***	(0.001)
JOYSCIE	0.173 ***	(0.001)	0.005 ***	(0.001)
Information diet				
EcoWebVisit	−0.005 ***	(0.001)	0.037 ***	(0.001)
BlogsVisit	−0.060 ***	(0.001)	0.015	(0.001)
BroadScTVprog	−0.032 ***	(0.001)	−0.008 ***	(0.001)
BroadScBooks	−0.024 ***	(0.001)	0.004 **	(0.001)
BroadScWeb	−0.050 ***	(0.001)	0.005 ***	(0.001)
MagScArtNewsp	−0.025 ***	(0.001)	0.017 ***	(0.001)
ScClubAttend	−0.021 ***	(0.001)	0.029 ***	(0.001)
Demographic & economic factors				
AGE	0.067 ***	(0.003)	0.007 **	(0.003)
WEALTH	0.006 ***	(0.001)	−0.043 ***	(0.001)
ESCS	0.160 ***	(0.001)	0.088 ***	(0.002)
MISCED	−0.036 ***	(0.001)	−0.006 ***	(0.001)
FISCED	0.021 ***	(0.001)	−0.016 ***	(0.001)
(Gender)M/F	0.089 ***	(0.001)	−0.171 ***	(0.001)
(IMMIG)2/1	−0.067 ***	(0.002)	−0.120 ***	(0.002)
(IMMIG)3/1	−0.004	(0.003)	−0.092 ***	(0.003)
(GradeLev)8/7	0.046 ***	(0.012)	0.109 ***	(0.013)
(GradeLev)9/7	−0.173 ***	(0.010)	0.190 ***	(0.011)
(GradeLev)10/7	−0.088 ***	(0.010)	0.274 ***	(0.011)
(GradeLev)11/7	0.038 ***	(0.010)	0.395 ***	(0.011)
(GradeLev)12/7	−0.648 ***	(0.022)	0.700 ***	(0.023)
country-specific Effects				
(CNT)CAN/USA	0.152 ***	(0.003)	0.344 ***	(0.003)
(CNT)MEX/USA	−0.344 ***	(0.002)	0.399 ***	(0.002)
Awareness (TAgmo)			$\hat{\gamma} = 0.025$ ***	(0.001)
Log-likelihood		−3,558,168.2		−3,049,266.9
BIC		7,116,610.6		6,098,808.1
AIC		7,116,392.3		6,098,589.8

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A4. MLE Results for Youth's NPT Awareness and Expectations within NAFTA.

N 17,981	Awareness Coef.	(s.e.)	Expectations Coef.	(s.e.)
Cutoff 2	$\hat{\mu}_2 = 1.428$ ***	(0.001)	$\hat{\delta}_2 = 1.023$ ***	(0.001)
Cutoff 3	$\hat{\mu}_3 = 2.693$ ***	(0.001)		
(Intercept)	0.945 ***	(0.042)	−1.220 ***	(0.045)
Affective factors				
IntBiosph	0.146 ***	(0.001)	0.010 ***	(0.001)
IntScPrevDis	0.048 ***	(0.001)	0.028 ***	(0.001)
JOYSCIE	0.138 ***	(0.001)	−0.015 ***	(0.001)
Information diet				
EcoWebVisit	−0.042 ***	(0.001)	0.064 ***	(0.001)
BlogsVisit	−0.071 ***	(0.001)	−0.013 ***	(0.001)
BroadScTVprog	−0.032 ***	(0.001)	0.027 ***	(0.001)
BroadScBooks	−0.033 ***	(0.001)	0.045 ***	(0.001)
BroadScWeb	−0.038 ***	(0.001)	−0.021 ***	(0.001)
MagScArtNewsp	−0.039 ***	(0.001)	0.010 ***	(0.001)
ScClubAttend	0.035 ***	(0.001)	0.064 ***	(0.001)

Table A4. *Cont.*

N 17,981	Awareness Coef.	(s.e.)	Expectations Coef.	(s.e.)
Demographic & economic factors				
AGE	0.032 ***	(0.003)	0.045 ***	(0.003)
WEALTH	0.021 ***	(0.001)	−0.014 ***	(0.001)
ESCS	0.058 ***	(0.001)	0.062 ***	(0.002)
MISCED	−0.019 ***	(0.001)	−0.004 ***	(0.001)
FISCED	0.023 ***	(0.001)	−0.010 ***	(0.001)
(Gender)M/F	0.150 ***	(0.001)	−0.138 ***	(0.001)
(IMMIG)2/1	−0.129 ***	(0.002)	−0.027 ***	(0.002)
(IMMIG)3/1	0.054 ***	(0.003)	0.034 ***	(0.003)
(GradeLev)8/7	−0.084 ***	(0.012)	0.238 ***	(0.013)
(GradeLev)9/7	0.007	(0.010)	0.463 ***	(0.011)
(GradeLev)10/7	−0.010	(0.010)	0.631 ***	(0.011)
(GradeLev)11/7	0.115 ***	(0.010)	0.688 ***	(0.011)
(GradeLev)12/7	0.615 ***	(0.022)	0.007	(0.022)
country-specific Effects				
(CNT)CAN/USA	0.071 ***	(0.003)	0.150 ***	(0.003)
(CNT)MEX/USA	−0.195 ***	(0.002)	0.497 ***	(0.002)
Awareness (TAnpt)			$\hat{\gamma}$ = 0.067 ***	(0.001)
Log-likelihood		−3,321,837.3		−2,847,252.3
BIC		6,643,948.8		5,694,779.0
AIC		6,643,730.5		5,694,560.7

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

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