Economic Costs of Caffeine Beverage Restrictions and Withdrawal: A Global Perspective

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Abstract

This study investigates the nature and workings of the caffeine industry, it also examines its importance, production patterns and contributions to GDP in major countries around the world. The caffeine industry produces caffeinated beverages especially energy drinks, coffee and tea. The core of this study revolves around the dilemma on the economic and health cost of caffeinated beverage control. Today the caffeine market is worth more than $10 billion dollars and is estimated to reach $320 billion by 2032, it is growing fast with increased consumption of coffee, tea, and energy beverages, these drinks do not simply form part of the everyday lives, but they are also important in the economies of most countries. As it is, countries such as Brazil, Vietnam and Colombia produce and export caffeine in large volumes boosting their Gross Domestic Product. Brazil alone consumes 3 million metric tons of coffee generating 6 billion yield in exports and provides people with 8 million jobs, new manufacturers like Nigeria, have not fully attained their economic capacity but are getting there. Caffeine plays an essential role in productivity within the real sector like the industrial, healthcare, ICT the education and other allied sectors. This study findings showed that caffeine withdrawal and restrictions caused productivity losses based on empirical evidence from Japan, the United Kingdom, and the United States revealing that it caused productivity declines, revenue losses, and disruptions in crucial sectors dependent on cognitive execution. Based on these findings, the study recommends that beverage manufacturers should reformulate high-caffeinated beverages into moderate or low-caffeinated beverages without compromising efficiency, taste and marketability.

Keywords: Caffeine, Energy drink, Methylxanthine.

Introduction

Because more people are consuming caffeinated beverages, the market for caffeine has risen significantly. Today the global market for caffeine is estimated to be worth more than $10 billion, rising from $3.4 billion in 2023, as reported by Yahoo Finance (2024). Caffeine's growing use in varieties of industries, including food, beverages, and medicines, and it is anticipated to soar because of the demand for energy drinks and specialty coffee in regions like North America and Europe accounts for over 45% of the world's caffeine consumption, giving the product substantial market shares.

As data about excessive caffeine usage continues to grow, public health regulators have been genuinely concerned about this growing demand for products containing caffeine, and efforts at enforcing laws that restrict caffeine access have been undergoing considerations. However, the economic cost of caffeine restrictions are overlooked in public health research. Energy drink manufacturers maintain that their products were safe and appropriate for consumers, but the perceived unsafety of these items is currently the subject of serious debate among public health stakeholders, while some reports have indicated that energy drinks have negative health impacts, food technologist and medical scientists are still in dilemma as to the health impacts of energy drinks.

The Global Caffeine Market

According to Market Research Future (2023), by 2032, the market for caffeinated beverages is projected to have grown to about $320.0 billion, the caffeine industry is booming due to the energy drink market, which remains the fastest-growing dominated by beverages like Red Bull, Monster, Rockstar and others having significant caffeine content and other active ingredients like Taurine, Guarana, Ginseng and few more which are marketed to young athletes and adults.

Energy drinks were designed to increase both physical and mental stimulation, but there are growing concerns about the number of caffeine products available on the market and the formulations of energy drinks which contains energy boosting chemicals with an addictive sweetened taste, the product now competes with bottled water earning the lead as the fastest-growing industry globally Aonso-Diego et al. (2024).

Another important source of caffeine is coffee and tea which dominates the market, they are commercially available in North America, Europe, Asia-Pacific, and North Africa. Tea's wide range of consumers can be attributed to its adaptability in both hot and cooled forms as well as its connection to wellness. Because of their antioxidant qualities, green and black teas in particular are popular among consumers who are health-conscious. Additionally, soft drinks, particularly Colas like Pepsi and Coca-Cola, have traditionally played major roles in the global application of caffeine. Caffeine is still a key component of many carbonated drinks, even though soda use has somewhat decreased among health-conscious individuals due to sugar concerns, Coca-Cola is a well-known worldwide brand with yearly sales of over $40 billion.

Coffee, tea, cola, energy drinks, and over-the-counter pharmaceuticals are just a few of the many ways that people consume caffeine, which is the most widely used stimulant and psychoactive drug in the world. According to Samoggia and Rezzaghi (2021) more than 80% of adults take caffeine on a daily basis, energy drinks have been increasingly popular with the biggest consumption rate seen in countries like the United States, Finland, Brazil, and Italy.

For many, particularly those in the construction, transportation and manufacturing, caffeine is crucial because it promotes alertness, mood regulation, and performance (Einöther & Giesbrecht, 2013). Because energy drinks can raise cognitive levels, prior studies in Turkey indicated that both men and women felt stronger and more energised after its consumption (Kalkan et al., 2018).

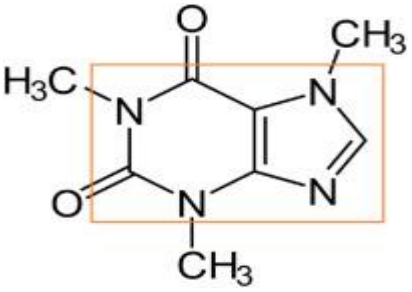
Masengo et al. (2020), in a previous study revealed that energy drinks were potent in improving moods and lessening fatigue, also having psychoactive effects because of its high caffeine concentration, which ranges from 50 mg to as much as 505 mg per bottle or can, people who take most frequently take energy drinks to give themselves surge of energy that improves their mood and cognitive function.. Energy drinks (EDs) are designed to increase both mental and physical energy), they contain energy-boosting ingredients, such as caffeine, Taurine, herbal extracts, sugar, and B vitamins. Samoggia &Riedel (2018) maintained that Caffeine-containing products are consumed at global level and is common among different consumers' age groups, and are used for number of reasons, from socialization to mental and physical alertness, they revealed that consumers with the desirable need for improved memory, increased alertness, elevated mood, mental energy and physical energy it supplies demand for the products, this was also

supported by Agòston (2008) in a similar study confirmed that the three main motives of energy drink consumption to be the taste, drinking habit and alertness. Perez-Lopez et al. (2014), reported from a previous study that consumption of approximately 3 mg/kg of caffeine in the form of energy drinks significantly improved the physical performance of female volleyball players.

Alford et al. (2001) in another study examined how 36 people were affected by a market-leading energy drink, based on subjective alertness, physical endurance, and psychomotor performance (reaction time, focus, and memory) were all evaluated on cycle ergometers, they demonstrated that the investigated energy drink markedly improved aerobic performance (maintaining maximum speed) and aerobic endurance (maintaining 65–75% maximum heart rate), increased perceived alertness was demonstrated by the notable improvement in mental function, which included memory and focus.

Caffeine beverages are widely accepted by the Food and Drug Administration (FDA) as safe in the United States, also the European Food Safety Authority recommended to non-pregnant adults who consume up to 400 mg of caffeine daily (about 5.7 mg/kg of body mass daily) do not have any health or safety concerns, and pregnant and lactating women who consume up to 200 mg daily have no concerns for either the foetus or the breastfed infants. The amount of caffeine in a cup of coffee varies from 80 to 175 mg, depending on the type of "bean" (seed), roasting method, and preparation method (e.g., drip, percolation, or espresso). However, since energy drinks also contain Taurine, Guarana extracts, and Ginseng, there is no solid proof that caffeine causes any major negative consequences McCrory et al. (2017).

Figure 1: ***Caffeine structure***



The chemical structure of caffeine is very similar to the structures of other metabolic compounds like purines and adenosine. Beyond its stimulant effect, caffeine's structure also enables it to increase dopamine signalling indirectly by modulating adenosine's inhibition of dopamine receptors.

Medically, the addition of caffeine (100–130 mg) to commonly prescribed pain relievers such as paracetamol or ibuprofen modestly improves the condition of people who suffer pains (for a maximum duration of six hours). Derry et al. (2014) in a study affirmed that consumption of caffeine after abdominal surgery shortens the time to recovery of normal bowel function and shortens the length of hospital stay.

Caffeine is a naturally occurring stimulant that is a member of the methylxanthine class and is most frequently found in coffee, tea, and numerous energy drinks. With molecular weight of roughly 194.19 g/mol and the molecular formula $C_8H_{10}N_4O_2$, it is known chemically as 1,3,7-trimethylxanthine. At positions 1, 3, and 7 of the purine ring, three methyl groups are joined to nitrogen atoms to form xanthine core, a purine base chemically similar to adenine and guanine.

Table 1: Common Caffeine Forms

Forms	Description	Use
Coffee Beans	Primary natural source of caffeine	Brewed beverages
Tea Leaves	Source of caffeine (and theanine)	Tea production
Green Coffee Extract	Natural extract	Energy drinks, supplements
Synthetic Caffeine Powder	Lab-made, cheaper to mass-produce	Soft drinks, energy drinks, pharmaceuticals
Guarana/ Yerba Mate Extract	Botanical caffeine sources	Natural/organic energy drinks

Countries like Canada and members of the European Union have implemented labeling laws mandating caffeine quantity disclosures and warnings, also marketing restrictions, especially for energy drinks to protect consumers, such regulations can increase compliance costs for manufacturers, particularly small and medium-sized enterprises (SMEs). Taxation of caffeinated beverages as seen in Mexico and the UK reduced consumption but also altered market demand. In

2014 Mexico's government implemented an excise tax of 1 Mexican peso per liter (about 5.5 US cents) on energy drinks with added sugar, this policy led to significant decline in beverages sales in the first year and also resulted in job shifts within beverage supply chains Colchero et al., 2016). Studies revealed that imposing taxes on caffeine could deter investment in the beverage sector, especially in emerging economies. Several countries restrict energy drink sales to minors, while others like Lithuania and Latvia have implemented broader bans in schools. These policies can significantly reduce market size and profitability, especially in retail and the commercial sectors.

Table 2: Contribution of Caffeine Production and Consumption in Selected Countries (2023 Estimates)

Country	Major Caffeine Source	Annual Production (Metric Tons)	Export Value (USD Billion)	Domestic Consumption (kg per capita/year)	Contribution to GDP (%)	Employment (Caffeine-related, est.)
Brazil	Coffee	3,000,000	$6.0	6.0	1.5%	~8 million
Vietnam	Coffee (Robusta)	1,800,000	$3.5	2.2	3.0%	~2.6 million
Colombia	Coffee (Arabica)	900,000	$2.8	1.8	1.2%	~1.6 million
India	Tea & Coffee	Tea: 1,300,000 Coffee: 320,000	$2.0	0.6 (Coffee) 0.8 (Tea)	0.8%	~3.5 million
Ethiopia	Coffee	450,000	$1.2	2.4	1.3%	~2 million
USA	Importer & Consumer	N/A	N/A	4.2	~0.3% (retail/food)	~1 million (coffee industry)
China	Tea & Emerging Coffee	Tea: 2,700,000 Coffee: 130,000	$2.5	0.4 (Coffee) 1.2 (Tea)	0.6%	~3 million
Nigeria	Emerging Coffee Producer	89,000 (mostly Robusta, wild tea)	$0.06	0.15 (mainly tea and energy drinks)	<0.1%	~150,000 (formal + informal sect

The table presents data on caffeine production and consumption across eight countries, highlighting their major caffeine sources, annual production volumes, export values, domestic consumption rates, GDP contributions, and employment figures related to the caffeine industry.

Brazil stands as the world's largest caffeine producer, primarily through coffee. It produces about 3 million metric tons annually and earns approximately $6.0 billion in export revenue. Coffee plays a significant role in Brazil's economy, contributing 1.5% to its GDP and supporting an estimated 8 million jobs in caffeine-related sectors. Domestic consumption is also high, at 6.0 kg per capita per year, indicating both strong global and local demand.

Vietnam, known especially for its Robusta coffee, produces 1.8 million metric tons yearly, generating around $3.5 billion in export value. Caffeine (especially coffee) contributes more significantly to its national economy at 3.0% of GDP, and it provides employment to about 2.6 million people. While domestic consumption is more modest at 2.2 kg per capita, Vietnam's role as a major exporter is clear.

Colombia is the leading producer of Arabica coffee, producing 900,000 metric tons annually. It earns approximately $2.8 billion in exports, contributes 1.2% to GDP, and sustains about 1.6 million jobs. Consumption within Colombia is relatively lower at 1.8 kg per capita/year, reflecting its export-focused model.

India contributes significantly to both tea and coffee production, with 1.3 million metric tons of tea and 320,000 metric tons of coffee produced annually. Its caffeine exports are valued at about $2.0 billion, contributing 0.8% to GDP and providing employment to approximately 3.5 million people. Domestic consumption varies: 0.8 kg per capita for tea and 0.6 kg for coffee, suggesting traditional preference for tea but growing coffee interest.

Ethiopia, historically known to be the birthplace of coffee, produces 450,000 metric tons annually, earning $1.2 billion in exports. Caffeine contributes 1.3% to GDP, and the industry employs around 2 million people. With 2.4 kg per capita/year, Ethiopia also has one of the highest domestic consumption rates among developing countries.

The United States is not a major producer of caffeine, but it consumes and imports it majorly. It has no other notable production of its own, and still, its usage rate is high at 4.2 kg per capita/year. The caffeine implementations, particularly in the retail and food services sectors, make up approximately 0.3 per cent of GDP and employ approximately 1 million people because the country has a deeply rooted coffee culture and consumption of caffeinated products.

China, as a tea-consuming country also produces a rather significant 2.7 million metric tons of tea metric tonnes annually. It has an approximate export value of 2.5 billion dollars with a percentage of about 0.6 in GDP. The level of domestic consumption is low: 0.4 kg per capita/year of coffee and 1.2 kg of tea. However, there is good potential in the market, as the caffeine industry sustains about 3 million jobs.

Nigeria is also an emergent producer of caffeine; especially its output is 89,000 metric tonnes, and the amount of exports is very low at about $600,000. Caffeine represents less than 0.1 per cent of the national GDP, and the domestic consumption is also at a modest level of 0.15 kg per capita, mostly produced by tea and carbonated beverages. It is estimated that 150,000 employees work in the industry, in both the formal and informal sectors, which should indicate an underutilised economic potential.

Table 3: Relevant Agencies and Regulatory Bodies on Caffeine Production and Consumption in Selected Countries

Country	Agencies/regulatory bodies
Brazil (coffee production, export, employment)	International Coffee Organization (ICO), 2023; FAOStat; Brazilian Coffee Exporters Council
Vietnam (coffee production, export value)	Vietnam Coffee-Cocoa Association (Vicofa); International Coffee Organization (ICO), 2023
Colombia (arabica coffee, export, GDP contribution)	Federación Nacional de Cafeteros de Colombia; World Bank Reports, 2022-2023
India (tea and coffee production, domestic consumption)	Tea Board of India; Coffee Board of India; FAOStat; Indian Ministry of Commerce
Ethiopia (coffee production, export earnings, employment)	Ethiopian Coffee and Tea Authority (ECTA); International Trade Centre (ITC); World Bank 2022
USA (coffee consumption, employment)	National Coffee Association (NCAUSA) Coffee Trends Report 2023; USDA; Statista
China (tea production, rising coffee consumption)	China Tea Marketing Association; USDA Foreign Agricultural Service

Nigeria (coffee potential, consumption trends)	Nigerian Export Promotion Council (NEPC); National Bureau of Statistics (NBS); FAO Nigeria.

Brazil

The ICO monitors trade volumes and prices on an international basis and puts the output of Brazil in perspective. The FAOStat provides agricultural data such as the quantity of production and utilities of land, also the Brazilian Coffee Exporters Council provides information on export statistics and international trade analytics. These entities bring out the fact that Brazil has dominated the world market in coffee supply, has huge exports, and that the industry has provided employment to about 8 million people. This indicates the significant role played by coffee in the Brazilian economy in terms of the GDP and employment.

Vietnam

Production and export data as well as policy updates are done by the Vietnam Coffee-Cocoa Association (Vicofa), and on the international scene, emerging global market trends are given by the International Coffee Organisation (ICO). All these sources provide information about the growth of the economy of Vietnam which is promoted by coffee and its competitiveness in the export markets with production of approximately 1.8 million metric tons per year and USD 3.5 billion in export value.

Colombia

A national stakeholder is the Federacion Nacional de Cafeteros de Colombia, which gives the statistics on production, supporting the farmers, as well as the export statistics. Coffee is not only an identity and economic foundation in Colombia, but these sources emphasise its significance for exports and connection to the livelihood of smallholder farmers.

India

The Tea Board and Coffee Board of India are regulators that monitor production, encourage exports and deal with standards of quality. The FAOStat provides data on agriculture as the Indian

Ministry of Commerce provides trade analytics. These organisations sustain the Indian dual beverage economy and make clear the dominance of tea in the domestic market and the rise of coffee as an export product, most especially to the southern states.

Ethiopia

The ECTA controls production, certifies export quality and gives employment statistics. ITC provides trade-related assessments, whereas the World Bank takes a larger view of developmental aspects. These sources of data affirm that coffee brings good foreign exchange revenues and forms employment for millions of people. This collaboration of these institutions demonstrates Ethiopia's effective economic exploitation of coffee as a driver of economic growth; similarly, tea exports form a major share of foreign exchange for countries like Sri Lanka and Kenya. These exports help stabilise currencies, reduce trade deficits, and stimulate economic development in agricultural regions.

Nigeria

Nigerian Export Promotion Council (NEPC), National Bureau of Statistics (NBS), FAO Nigeria reports coffee production and growing consumption trend. The **NEPC** promotes exports and monitors agribusiness development, while the **NBS** provides demographic and consumption data. **FAO Nigeria** delivers agricultural production statistics. Collectively, these sources promotes the production value chain in boosting the industry's potential to grow the Nigerian economy.

China

China is a leading global tea producer, with its coffee consumption rapidly increasing. The Chinese Tea Marketing Association provides production statistics and export data for tea and market insights into urban coffee trends and consumer shifts, while USDA delivers consumption and import data. These sources collectively portray a dual trend of traditional tea dominance and emerging coffee culture, indicating significant market potential and evolving preferences in China's beverage economy.

Global Costs and Benefits

Caffeinated beverages support millions of jobs worldwide. The coffee and tea industries, in particular, provide livelihoods for over 125 million people globally, especially in developing countries across Africa, Latin America, and Asia. From smallholder farmers growing coffee beans in Ethiopia and Vietnam to factory workers processing tea in India and Kenya, these beverages are deeply woven into the socioeconomic fabric of several nations. Teachers, aviation workers, trucking, rail transport, and students are heavy consumers of caffeine to maintain focus and performance, in sectors where cognitive strengths critical such as caffeine withdrawal could increase poor productivity, accidents, and fatalities.

In developed economies, caffeinated beverages have become core parts of the retail and hospitality sectors. Global franchises like Starbucks, Costa Coffee, and Dunkin'Donuts among several others have turned coffee consumption into a cultural and commercial concern. These companies generate billions in revenue annually and create employment opportunities ranging from sales agency to supply chain management, the expansion of such retail outlets also encourages the growth of auxiliary businesses in logistics, packaging, and equipment supply.

The caffeinated beverage industry has seen significant transformation, especially among health-conscious individuals; consumers are increasingly interested in beverages with added vitamins, no sugar, or organic labels. This trend has spurred product diversification; from organic brewed caffeine drinks to healthy energy beverages, these innovations fuel competition and attract investment from both established companies and start-ups.

According to a meta-analysis conducted by Juliano & Griffiths (2022), caffeinated beverage restrictions among employees caused decline in the ability to conduct tasks based on sustained attention, problem-solving, and coordination, it also could trigger poor workers' productivity, which greatly affect the output of companies, particularly those in the knowledge-based areas in terms of finance, IT, law and healthcare, also caffeine withdrawal may cause low productivity in schools, high absenteeism with long-term outcome on human capital development. These have an impact on the effectiveness of the work area, particularly in industries that apply knowledge and do labour-intensive work. As an example, the widespread restriction of caffeine availability owing to the public health actions could potentially lead to decreasing productivity, greater rates of absenteeism, and slower accomplishment of tasks in the short term, it could also lead to declining

productions, poor safety measures and a rising pace of errors. Although these economic costs are not always quantifiable, indirect costs, such as downtime of the machine or injuries at the workplace could add up to this numbers

Across the United States, caffeine has been shown to improve concentration among certain employees, such as shift workers Ker (2010). Liira (2014), maintained that a decrease in the consumption of caffeinated drinks might have the potential to decrease productivity and safety among certain occupational groups.

Discussion and Findings

United Kingdom

The United Kingdom, in 2018, levied consumers on drinks with sugar content, essentially targeted towards caffeinated soft drinks, this caused major shift among manufacturers in the production patterns and concentration of certain ingredients in their beverages, thereby cutting down the amount of sugar and in some cases caffeine, this helped the cause of public health as directed by the country's health regulators, but these companies spent a huge amount on the reformulation of their products and experienced a significant decline in revenue and overall profitability.

European Union

Denmark, Turkey, Norway, Uruguay, Iceland and France banned energy drinks due to the high levels of caffeine consumption among young people. In 2008, the French government overturned the ban following findings from an assessment by the European Food Safety Authority which pointed out that there was no definite risk (Oddy et al., 2008). The sale of the energy drinks is permitted in almost all EU member states today; however, there are limited restrictions imposed on the sale of energy drinks to children in Norway and Denmark, Hungary, on the other hand taxes beverages that contain over 100 mg of Taurine or over 1 mg of Methylxanthines per 100 ml at approximately euro 0.81/l (NIHD, 2013). This made sales volumes decline significantly in convenience stores, posting reduced turnover and declining profitability, manufacturers also went into alternative beverages leading to job cuts.

Japan

Employees in the fast-paced technology industry in Japan are used to relying on vending machine coffee and energy drinks during the long hours they work. According to a survey conducted by the Tokyo health and wellness centre, a temporary nationwide proposal to implement a caffeine tax was being discussed, 37.8 percent of employees in tech industries slowed the consumption of caffeine, and 61.8 percent employers complained of a productivity decline. This brought about the downturn in performance around that week, which was estimated to cost the Tokyo tech industry about 14 million dollars' worth of output losses.

According to a work by Cooper et al. (2021), caffeine-dependent users who abstained for a few days showed major decreases in cognitive performance. When millions of the working population decide to stop caffeinated beverages on the same day because of a policy or supply alteration, this could cause structural economic crises, with this quantifying the economic cost of caffeine withdrawal being huge due to its consumption patterns, productivity metrics and the health system.

Withdrawal of caffeinated beverages is associated with elevated anxiety, moodiness, and even depression among the users who consume the drug heavily (Meredith et al., 2013), notable changes in the behaviour of the deprived population of caffeine may have indirect implications for maintaining employment, decision-making, and social interactions, overloading welfare systems and employers.

United States

Even though the US did not place national ban on caffeine, localized efforts were put to control caffeine intake, some universities have taken local approach to control and restrict caffeine consumption on campus, such as limiting access in specific areas or promoting weeks without caffeine sales in cafeterias. The college administrators noted that there were dangers of overconsumption of caffeine, most especially among the students, who were already experiencing stress, anxiety, poor sleep, high heartbeat rate, among other health conditions. Some university cafeterias implemented the caffeine bans and promoted caffeine-free sales week campaigns; these control measures also took place in some workplaces. Due to these restrictions on consumption, students and employees showed low levels of enthusiasm, high absenteeism, and poor

concentration, while on the other hand majority of cafeterias saw a sharp drop in revenue and overall profitability.

Conclusion

The relevance of caffeinated drinks in the global economy is immense; their efficacy in medical practices, agricultural international trade and employment cannot be overemphasised. Caffeine restrictions come with high economic costs. Restrictive legislation comes with huge economic consequences, medical costs and industrial consequences. The beverage industry remains a crucial part of the global economy as it shapes domestic policies, factor markets and development plans.

While protecting public health is essential, the caffeine beverage industry's role in trade employment, and workplace productivity cannot be overlooked, discretionary regulations are crucial to ensure that health gains do not come at unsustainable economic costs. The future of caffeine regulation must be balanced, seeing it securing every individual's right to survival and protecting the economy. Stakeholders need to remain committed at investing sustainably in activities that balance trade policies ensuring that this booming sector retains its viability and remains competitive in the long term.

Recommendations

As a matter of moral suasion, public health regulators should persuade beverage manufacturers to reformulate high-caffeinated beverages into moderate or low-caffeinated beverages without compromising efficiency, taste and marketability.

Also, governments should facilitate incentives to promote favourable industry initiatives through tax cuts, research grants and access to new markets for new and existing innovative products. This collaboration would encourage corporate responsibility to secure commercial interests with health concerns to help the industry retain its employees and maintain its revenue and productivity.

Educating the public about caffeine consumption and other strategic initiatives should offer guidance on managing caffeine dependence and choosing alternatives. These awareness initiatives

should foster trust and ensure that health-focused legislation is met with informed cooperation rather than resistance.

Health agencies and investors can support research that minimises caffeine contents while still maintaining its effectiveness by introducing herbal infusions such as ginseng and vitamin-enriched beverages to augment the decline in caffeine concentration. This will encourage domestic production and innovation in this sector, opening new economic opportunities for employment, research and development.

To ensure the effectiveness of caffeine legislation while minimising unintended consequences, real-time economic monitoring systems are crucial. These systems can track variables such as employment rates in the beverage industry, shifts in consumer purchasing behaviour, tax revenue changes, and public health metrics.

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