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Trade Agreements and Economic Integration in Central Asia: Evidence from PPML Gravity and Event-Study DiD

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Table of Contents

List of abbreviations

ADB - Asian Development Bank

ATT - Average Treatment Effect on the Treated

CA - Central Asia

CIS - Commonwealth of Independent States

CPI - Consumer Price Index

CSDID - Callaway–Sant'Anna cohort-specific Difference-in-Differences

DiD - Difference-in-Differences

EAEU - Eurasian Economic Union

EU - European Union

FTA - Free Trade Agreement

GMM - Generalized Method of Moments

IRR - Incidence Rate Ratio

LOO - Leave-One-Out

OCA - Optimum Currency Area

PPML - Poisson Pseudo-Maximum Likelihood

SCO - Shanghai Cooperation Organization

TFI - Trade Facilitation Indicators

TWFE - Two-Way Fixed Effects

WDI - World Development Indicators

WTO - World Trade Organization

Abstract

This thesis analyzes economic integration in five Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) over 1995—2024, focusing on participation in the CIS free trade area, membership in the EAEU, and WTO accession. The empirical strategy proceeds in three steps. First, bilateral trade effects are estimated in a structural gravity framework using Poisson pseudo-maximum likelihood (PPML) with high-dimensional fixed effects, reporting policy coefficients as incidence rate ratios (IRR). Second, macroeconomic variables are studied using modern staggered Difference-in-Differences based on the Callaway–Sant'Anna cohort-specific estimator and event-study tools, with the main emphasis on CIS accession and CPI inflation. Third, system-GMM is reported as a dynamic benchmark to assess persistence and the role of common shocks. The gravity results indicate that joint WTO membership is robustly associated with higher intra-regional trade, while EAEU estimates are not stable across specifications. In the macroeconomic analysis, CIS accession is associated with lower CPI inflation, although event-time patterns suggest that some adjustment may precede formal entry. GDP per capita displays very strong persistence, and dynamic specifications with full time effects leave limited variation to separately identify policy coefficients. Overall, the results suggest that formal trade arrangements in Central Asia are more clearly related to trade integration and price stabilization than to robust, precisely estimated growth accelerations, and that growth-related estimates are sensitive to specification choices.

Keywords: Central Asia; regional integration; gravity model; PPML; IRR; WTO; CIS; EAEU; Difference-in-Differences; CPI inflation; GDP per capita; system GMM

Zusammenfassung

Diese Arbeit untersucht wirtschaftliche Integration in fünf zentralasiatischen Ländern (Kasachstan, Kirgisistan, Tadschikistan, Turkmenistan und Usbekistan) im Zeitraum 1995—2024 und betrachtet dabei die Teilnahme an der CIS-Freihandelszone, die Mitgliedschaft in der EAEU sowie den WTO-Beitritt. Die empirische Analyse erfolgt in drei Schritten. Erstens werden bilaterale Handelseffekte in einem strukturellen Gravitationsmodell mithilfe von Poisson-Pseudo-Maximum-Likelihood (PPML) mit hochdimensionalen Fixed Effects geschätzt; die Politikkoeffizienten werden als Incidence Rate Ratios (IRR) berichtet. Zweitens werden makroökonomische Variablen mit modernen staggered Difference-in-Differences-Methoden auf Basis des kohortenspezifischen Callaway–Sant'Anna-Schätzers sowie Event-Study-Werkzeugen analysiert, mit einem Schwerpunkt auf CIS-Beitritt und Verbraucherpreisinflation (VPI). Drittens dient System-GMM als dynamischer Benchmark, um Persistenz und die Rolle gemeinsamer Schocks zu beurteilen. Die Gravitationsschätzungen zeigen, dass eine gemeinsame WTO-Mitgliedschaft robust mit höherem intraregionalem Handel verbunden ist, während EAEU-Effekte über Spezifikationen hinweg nicht stabil sind. In der Makroanalyse ist das robusteste Ergebnis ein negativer Zusammenhang zwischen CIS-Beitritt und Inflation, wobei die Event-Time-Muster darauf hindeuten, dass Anpassungen teilweise bereits vor dem formalen Beitritt einsetzen können. Das BIP pro Kopf weist eine sehr starke Persistenz auf, und dynamische Spezifikationen mit vollständigen Zeit-Effekten lassen nur begrenzte Variation zur separaten Identifikation von Politikvariablen. Insgesamt sprechen die Ergebnisse dafür, dass formale Handelsarrangements in Zentralasien eher mit Handelsintegration und nomineller Stabilisierung als mit robust und präzise schätzbaren Wachstumsbeschleunigungen zusammenhängen; wachstumsbezogene Effekte sind zudem sensitiv gegenüber Spezifikationsentscheidungen.

Schlagwörter: Zentralasien; regionale Integration; Gravitationsmodell; PPML; IRR; WTO; CIS; EAEU; Difference-in-Differences; Verbraucherpreisinflation (VPI); Bruttoinlandsprodukt (BIP); System-GMM

Brief historical background

The Soviet Union dissolved in 1991, and the newly independent Central Asian republics—Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—transitioned from centrally planned economies to market-based systems. This transition created substantial institutional and macroeconomic challenges. In the early post-Soviet period, Russia, Belarus, and Ukraine initiated the Commonwealth of Independent States (CIS), which subsequently expanded to include most former Soviet republics and served as a platform for political coordination and economic cooperation (Mukhamediyev and Khitakhunov, 2017). Over time, the CIS framework incorporated trade-related initiatives, including free-trade arrangements; however, participation and implementation differed across Central Asian countries. Alongside the CIS, additional regional groupings emerged. The Eurasian Economic Union (EAEU), established in 2015 by Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russia, aims to deepen economic integration through a customs union and related institutional mechanisms. In Central Asia, engagement with the EAEU varies, with some countries participating fully and others maintaining looser forms of association, such as observer status. Central Asian countries also integrated—at different times—into the multilateral trading system through accession to the World Trade Organization (WTO). Kyrgyzstan joined in 1998, followed by Tajikistan in 2013 and Kazakhstan in 2015, as part of broader tariff and customs reforms (WTO, 1998, 2013, 2015). Uzbekistan and Turkmenistan remained outside the WTO for longer, with Uzbekistan reactivating its accession process more recently while Turkmenistan has remained largely outside multilateral trade disciplines (Normatov, 2018). This staggered sequence of accessions resulted in a mixed trade regime in Central Asia: some bilateral relationships are governed primarily by WTO rules, while others rely more heavily on regional agreements or bilateral arrangements. As a result, regional integration has proceeded through overlapping institutions rather than within a single unified framework. In addition, the Shanghai Cooperation Organisation (SCO), created in 2001, includes four Central Asian “stan” members (Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan) and focuses primarily on regional security cooperation, with an economic agenda centred on connectivity and infrastructure rather than deep market integration or monetary coordination (Incaltarau et al., 2022). More recently, policy discussions in the region have again raised the possibility of deeper economic cooperation, including stronger coordination in macroeconomic policy and, in some proposals, monetary integration (Normatov, 2018; Tukumov, Y., 2025).

Introduction

Central Asian countries (Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan) are linked by history, culture, and economy; however, their integration is still limited. Past free trade agreements and regional collaborations have yielded mixed results. Economic integration has advanced substantially and regional integration can help to enhance trade, stabilize inflation, encourage sustainable development and accelerate growth. As a benchmark, the European Union illustrates how deep, rules-based integration can substantially increase trade among members, although estimated magnitudes vary across methods and samples (Nagengast, Rios-Avila, and Yotov, 2025). For instance, the evidence indicates that for many entrants, EU membership raised per capita incomes on average roughly 10% in the first decade after accession (Campos, 2019).

Central Asia is rich in resources; it is even geo-strategically important, yet under-explored in this regard. The trade between these countries is still limited compared to their overall trade, as they mostly interact with countries outside the region. Production ties from the Soviet times have weakened and have not been fully recovered and rebuilt by new regional connections (Grafe, Raiser and Sakatsume, 2008; Mazhikeyev, Edwards and Rizov, 2015). Extra trade barriers are created because the region is landlocked, which causes high transport costs (Grigoriou, 2007). As an example, in Uzbekistan the import tariff and specific excise on automobiles exceeded 100% of import value in the late 2000s–2010s (Normatov, 2018), exemplifying how such barriers can suppress bilateral flows when there is no free trade agreement (FTA). In addition to that, recent attempts to modernize and update customs and ease the trade were not the same in all parts of the region (ADB, 2024). However, regional deals and agreements can help to increase trade with each other by simplified trade rules and reduced tariffs (Baier and Bergstrand, 2007). Moreover, mutual recognition of standards and improved trust in government policies can be an essential step to boost trade between the nations (Frankel and Rose, 1998). The empirical analysis focuses on intra-regional trade among the five Central Asian economies. Even so, the region remains strongly oriented toward extra-regional trade. Trade is concentrated in large external partners (most notably China and Russia) reflecting historical production and supply-chain linkages as well as high overland transport costs in a landlocked region (Grigoriou, 2007). In line with this pattern, OECD (2023) reports that imports from Russia accounted for 44.4% of Uzbekistan's total imports and 72.1% of Kyrgyzstan's total imports, while Tajikistan sourced 30.5% of its imports from China (UN ESCAP, 2023). Trade-facilitation progress has also been uneven across countries: OECD's Trade Facilitation Indicators (TFI) show substantial automation-related gains in Kazakhstan since 2017, but only limited improvements in Kyrgyzstan and Tajikistan and little measurable change in Uzbekistan over the same period. A policy overview shows that the intra-regional trade share increased from about 6.4% in 2014 to around 9% in 2022, although the overall level remains low (Tukumov, 2025). This pattern helps explain variation in intra-regional linkages and highlights the importance of

reducing border costs for regional integration (OECD, 2023). Against this background, this thesis asks whether existing regional trade agreements and recent institutional reforms in almost all Central Asian countries are associated with trade and macroeconomic patterns that would be favorable to a potential monetary union. Rather than assuming that these economies automatically converge towards a common steady state, the analysis focuses on how the Commonwealth of Independent States (CIS) FTA, the Eurasian Economic Union (EAEU), and World Trade Organization (WTO) accessions relate to bilateral trade, inflation dynamics and growth indicators among Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Research question and contribution

This thesis asks whether formal trade agreements in Central Asia measurably deepen economic integration and improve macro stability. The primary research question is:

Do CIS FTA participation, EAEU membership, and WTO accession increase intra-regional trade among the five Central Asian economies?

Two complementary questions follow:

i) Is CIS accession associated with a systematic change in inflation dynamics?

ii) Do these agreements show any robust association with income levels (GDP per capita), once persistence and common shocks are accounted for?

To answer these questions, the thesis is organized in two pillars. Pillar 1 estimates a gravity model of bilateral goods trade using Poisson pseudo-maximum likelihood (PPML) with rich fixed effects to evaluate whether joint CIS, EAEU and WTO membership is associated with higher intra-regional trade. Pillar 2 applies modern staggered Difference-in-Differences/event-study methods à la Callaway and Sant'Anna (2021) to macroeconomic variables, with a focus on the impact of CIS accession on CPI inflation and, to a lesser extent, on GDP per capita. In addition, Pillar 2B introduces a complementary dynamic-panel system-GMM benchmark that explicitly models the persistence of macro variables and tests whether WTO/EAEU/CIS membership has detectable effects once lagged dependent variables and common shocks are taken into account. While the CSDID design provides the main causal evidence on CIS and inflation, the system-GMM exercises serve primarily as a robustness-oriented benchmark, highlighting the dominant role of persistence and common shocks in this small macro panel.

Stylized facts and descriptive evidence

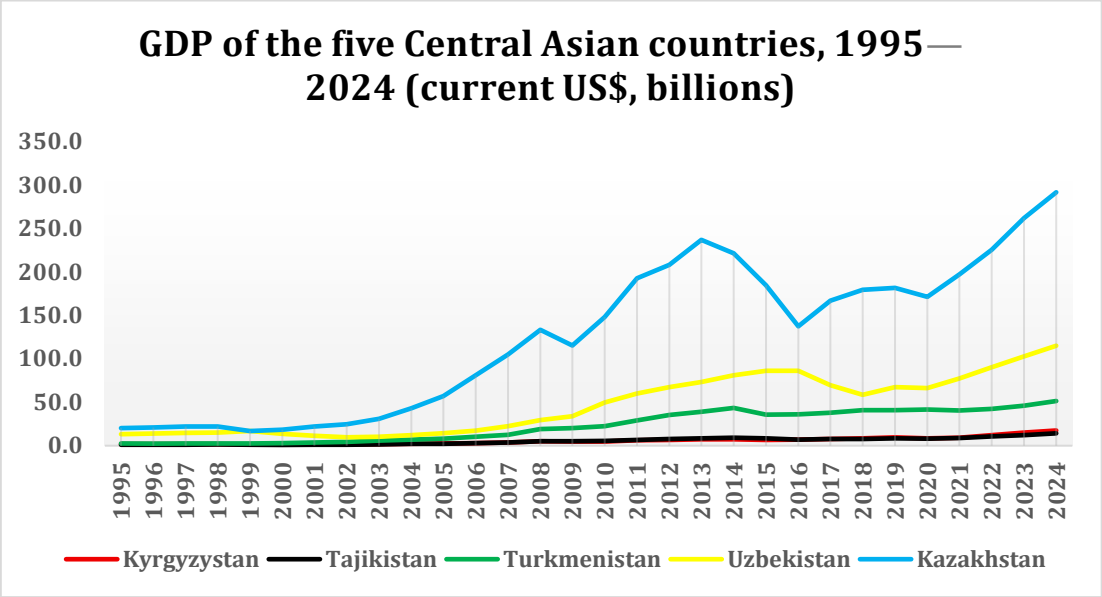

Figure 1. *GDP of the five Central Asian countries (current US$, billions)*
Source: World Bank, World Development Indicators (WDI).

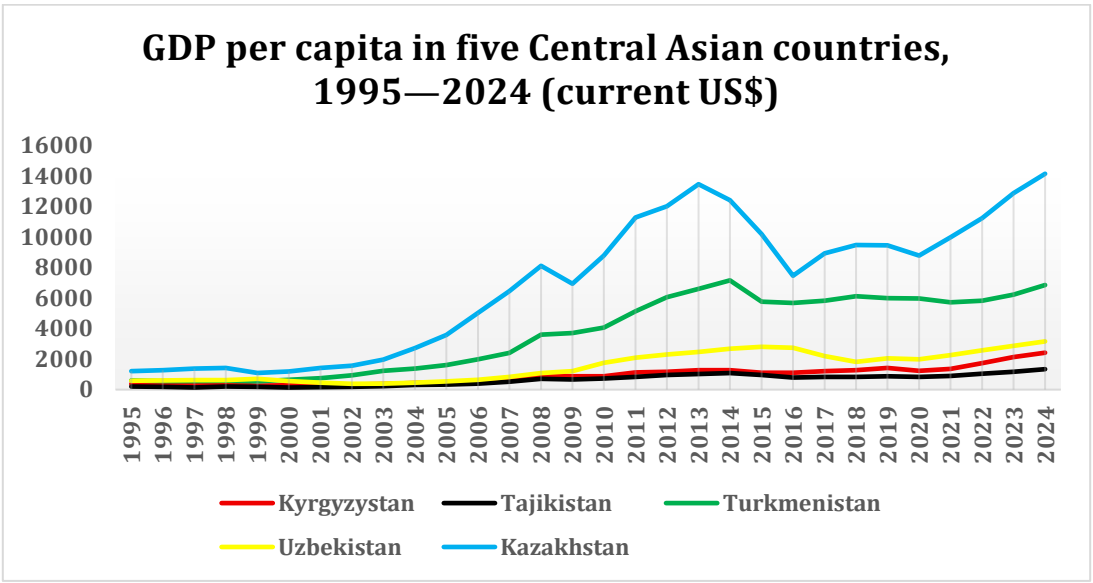

Figure 2. *GDP per capita in the five Central Asian countries (US$)*
Source: World Bank, World Development Indicators (WDI).

Figures 1 and 2 present descriptive evidence on GDP levels and GDP per capita in the five Central Asian countries over the period 1995—2024. On the one hand, the GDP-levels highlight large differences in the absolute size of economies within the region. Kazakhstan is by far the largest economy throughout the sample, followed by Uzbekistan and Turkmenistan, while Kyrgyzstan and Tajikistan remain substantially smaller. All five countries exhibit strong growth from the mid-2000s onward, a

pronounced slowdown around 2014–2016, and a renewed expansion in the post-2020 period. On the other hand, the GDP per capita shows a complementary perspective on living standards. Kazakhstan and Turkmenistan display persistently higher income levels per person, whereas Uzbekistan occupies an intermediate position and Kyrgyzstan and Tajikistan show lower but gradually increasing per-capita incomes. Importantly, the two figures together illustrate that large GDP levels do not automatically translate into equally high GDP per capita, reflecting differences in population size and demographic dynamics across countries. These stylized facts are included to provide a broad macroeconomic context for the region and to motivate the subsequent econometric analysis. They demonstrate substantial heterogeneity in both economic size and income levels, as well as common turning points over time, suggesting that macroeconomic variables in Central Asia are shaped by a combination of persistent country-specific factors and shared shocks. This motivates the use of panel methods with fixed effects and dynamic specifications in the following sections.

Literature review

Central Asian trade, geography and regional integration

Central Asia combines very low intra-regional trade shares with severe geographic and infrastructural constraints. Grafe, Raiser and Sakatsume (2008) demonstrate that the region's trade is still dominated by a few extra-regional partners and that intra-regional linkages remain shallow relative to other world regions. Landlockedness and distance from major markets raise trade costs, especially where infrastructure and border procedures are weak. Grigoriou (2007) and Lücke and Rothert (2006) find that CA economies face particularly high effective trade costs due to limited access to seaports, sparse transport networks and difficult terrain. More recent work emphasizes the role of trade facilitation and logistics: Felipe and Kumar (2012) and Karymshakov and Sulaimanova (2020) argue that customs efficiency, transport corridors and border cooperation can matter at least as much as tariff cuts for regional trade integration. At the same time, a growing literature has examined the pattern of CA's trade and the role of institutional arrangements. Mogilevskii (2012) describes how re-export activities, transit routes and the legacy of Soviet-era production structures shape trade patterns, while Mazhikeyev, Edwards and Rizov (2015) highlight the coexistence of "openness" and "isolation" in the trade performance of the former Soviet Central Asian republics. Mukhamediyev and Khitakhunov (2017) document that regional integration initiatives have had mixed and often country-specific effects on trade and output. More recent contributions by Cieślik and Gurshev (2022, 2024) evaluate Eurasian integration (CIS, EAEU and Russian WTO accession) and observe that the trade effects of these overlapping agreements are heterogeneous across pairs and sectors, reinforcing the idea that institutional integration in Central Asia is uneven and strongly shaped by political economy.

Figure 3 summarizes trade openness (measured as the ratio of exports plus imports divided by GDP) for these 5 "stan" economies since the mid-1990s. The

numbers on y-scale report a scale measure of external integration rather than a growth rate, and accordingly higher values (200 and 150) reflect larger trade flows relative to domestic output. All five countries are relatively open, with trade often exceeding 50% of GDP and reaching even much higher levels in some years in Kyrgyzstan and Tajikistan. Confirming the low intra-regional trade shares discussed above, this pattern confirms the fact that most integration still takes place with extra-regional partners rather than within CA itself.

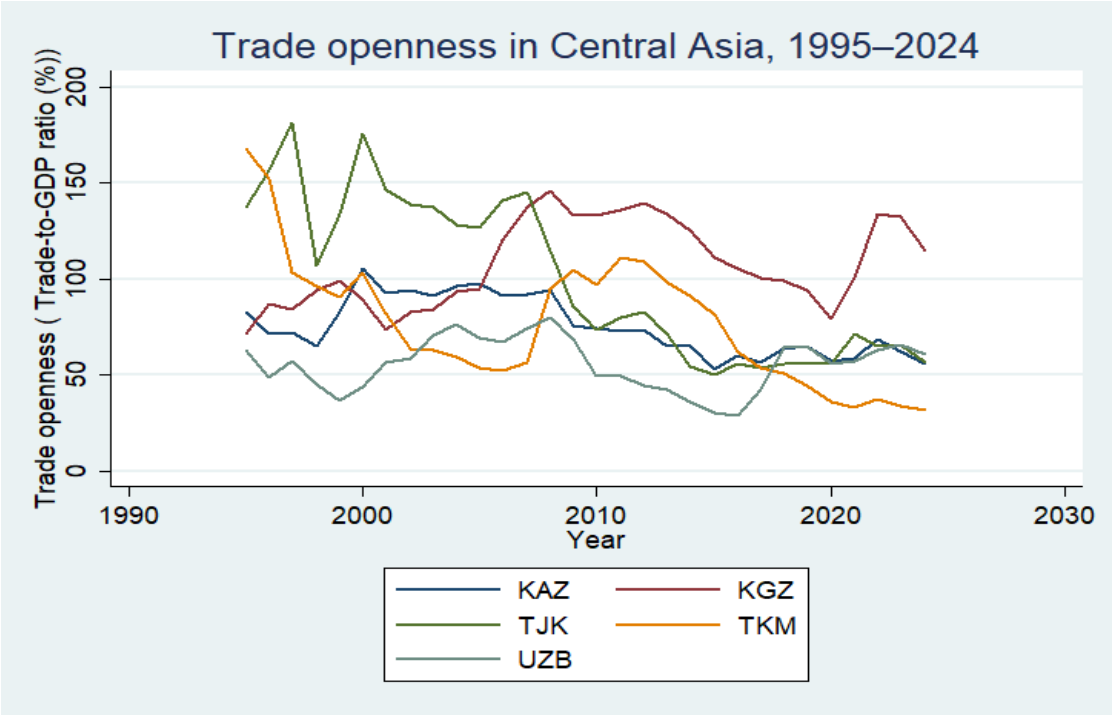

***Figure 3**. Trade openness in Central Asia, 1995—2024*
Source: World Bank, World Development Indicators (WDI).

Integration, growth and convergence

A second strand of literature studies how regional integration and openness translate into growth and convergence. Frankel and Rose (1998) show that monetary and trade integration can be linked to income convergence, but the strength of this link depends on how integration is measured and on country characteristics. For Eastern Partnership and Central Asian countries, Incaltarau et al. (2022) find that growth and convergence paths have diverged substantially since the 1990s, with energy-rich exporters following different trajectories than more diversified economies. Yorucu (2013) documents some evidence of β- and σ-convergence among Central Asian Turkic republics, but also stresses that convergence is incomplete and conditional on structural features. The convergence framework of Phillips and Sul (2007, 2009) is especially relevant conceptually: rather than assuming a single global convergence path, they allow for "convergence clubs" in which countries with similar characteristics converge towards each other but not necessarily towards the same world steady state. This view

fits Central Asia well, where integration with Russia, China and the EAEU, as well as domestic reforms, can generate club-like dynamics. The present thesis does not estimate formal Phillips-Sul clubs, but adopts the same spirit by treating convergence as conditional on trade agreements and country-specific factors, instead of assuming that the five economies automatically converge just because time passes.

Another chart (Figure 4) depicts the evolution of annual CPI inflation for the five CA countries. To begin with, inflation was high and volatile in the late 1990s and early 2000s especially in Tajikistan and Kyrgyzstan. Nevertheless, it has gradually moved into low ranges since then, with a few spikes around the global financial crisis and in the early 2020s. Therefore, this supports the view that price dynamics have become more stable, yet cross-country differences and shock episodes remain, which motivates the focus on inflation in the DiD analysis.

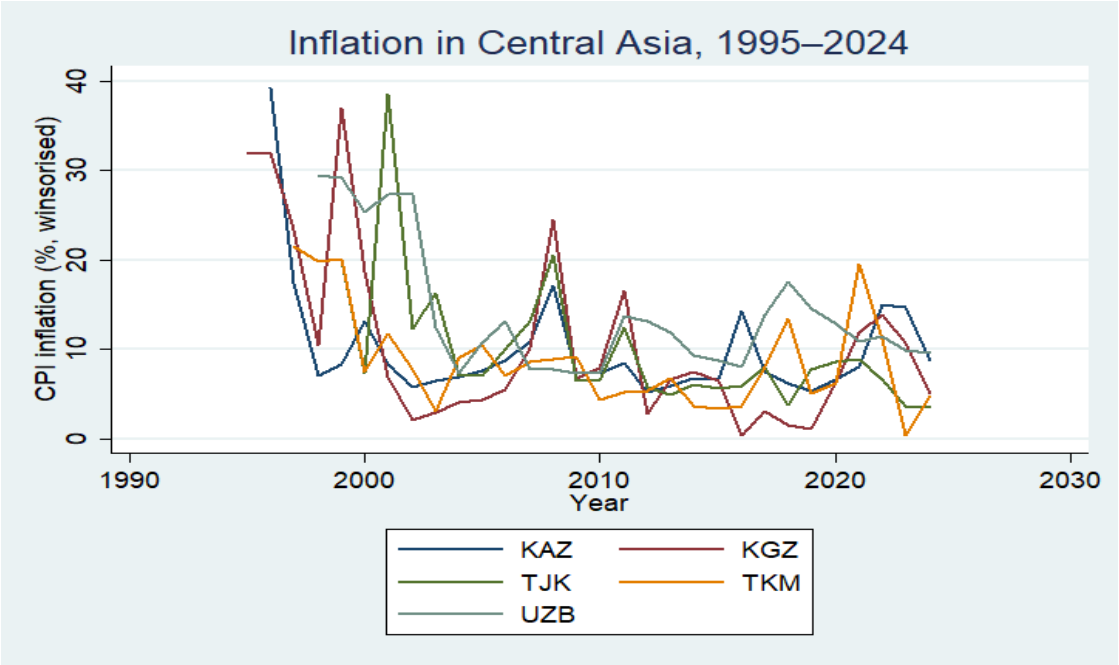

Figure 4. *CPI inflation in Central Asia, 1995—2024*
Source: World Bank, World Development Indicators (WDI).

Gravity models, regional agreements and WTO

A large literature models trade and macro linkages using gravity equations grounded in general equilibrium (Head and Mayer, 2014). Beyond Central Asia, gravity models are widely used to quantify the trade effects of regional trade agreements, customs unions and WTO membership. Early gravity studies often estimated large and unstable FTA (Free Trade Agreement) and WTO (World Trade Organization) coefficients in cross-section, leading to concerns about endogeneity and omitted multilateral resistance terms. Baier and Bergstrand (2007) show that simple cross-section estimates of FTA dummies can vary widely by year and even change sign, which they interpret as evidence that country pairs self-select into agreements based on characteristics that also drive trade (size, similarity, distance, remoteness). Empirically,

the consensus is to estimate multiplicative gravity with high-dimensional fixed effects and a Poisson pseudo-maximum likelihood (PPML) estimator to handle heteroskedasticity and zero flows (Santos Silva and Tenreyro, 2006). These choices reduce bias from log-linearization under non-constant variance and from selective deletion of zeros. Best practice also emphasizes exporter-time and importer-time fixed effects to proxy multilateral resistance and common shocks (Baldwin and Taglioni, 2006). Meta-studies and handbooks show that identification typically comes from within-pair variation after saturating fixed effects, which is directly relevant for evaluating regional agreements like the CIS FTA, the EAEU, or WTO accessions (Baier and Bergstrand, 2007; Head and Mayer, 2014).

In the panel setting, Baier and Bergstrand (2007) propose a gravity design with country-pair and time fixed effects and a dynamic treatment structure that allows FTA effects to build up over time. In that framework, they find that the average trade effect of an FTA is economically large, on the order of 80–100 percent after a decade, once endogeneity is controlled for. WTO accession is usually linked to stronger credibility of tariff bindings, more reliable dispute-settlement procedures, and trade-facilitation commitments, although the size of the effects differs across sectors and over time (Yotov et al. 2016). In the Eurasian context, institutional studies highlight the complexity created by overlapping arrangements (CIS, EAEU, bilateral deals) and the political-economy aspects of regulatory harmonization (Dragneva and Wolczuk 2012). These features support empirical strategies that allow for gradual and heterogeneous treatment effects and that are robust to selection into agreements. Methodologically, the gravity literature has moved towards specifications that respect the theoretical structure of trade costs and general-equilibrium "multilateral resistance" terms (Anderson and van Wincoop, 2003), and towards estimators that are robust to heteroskedasticity and zero trade flows. Many recent applications therefore estimate trade equations with exporter-year, importer-year and bilateral (pair) fixed effects, interpreting trade-agreement dummies as policy shifters conditional on unobservable bilateral affinity and common shocks. This general strategy motivates the gravity pillar of the present thesis, which uses PPML with rich fixed effects to evaluate the association between CIS, EAEU and WTO membership and bilateral trade flows for the five Central Asian economies.

Econometric approaches for trade and macroeconomic variables

When countries join trade agreements and unions in a staggered way, conventional two-way fixed-effects DiD can produce biased or hard-to-interpret averages (Goodman-Bacon, 2021). This happens because treated units at one point in time are compared to other units that are already treated, so the same country can act as both "treated" and "control" at different dates. New DiD methods address this problem by estimating separate cohort-specific ATTs and using clean comparison groups for each joining group (Borusyak, Jaravel and Spiess, 2024; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). Event-study designs based on these frameworks allow transparent pre-trend tests and dynamic treatment paths, which is particularly useful for

WTO entry (often preceded by multi-year reforms) and for EAEU/CIS where effects may build gradually. In practice, researchers report cohort-specific post-treatment effects, aggregated dynamic effects over economically meaningful windows, and joint significance tests for pre-treatment leads.

Macroeconomic indicators such as GDP per capita or inflation display strong persistence. Dynamic panel models are useful alongside DiD because they allow past values of the variable to enter directly into the specification (Arellano and Bond, 1991; Blundell and Bond, 1998). With macroeconomic panels that have many countries and relatively short time series, these models can easily create too many instruments or weak instruments. To avoid unreliable results, researchers usually limit the number of lags used as instruments, collapse the instrument matrix, and report the Hansen/Sargan tests, AR(1)/AR(2) serial-correlation tests, and the total number of instruments (Roodman, 2009). In the integration context, dynamic panels are often used as robustness checks: if policy indicators (e.g. WTO/EAEU/CIS membership) lose statistical significance once lagged dependent variables and fixed effects are included, this suggests that persistence and common shocks account for most of the variation in the variable, leaving limited remaining within-country variation for the policy indicators to explain. Across empirical strategies, a coherent robustness architecture is now standard. For gravity PPML, typical robustness checks include sensitivity to alternative fixed-effects structures (e.g. pair vs pair-time), alternative clustering (e.g. two-way by exporter and importer), dropping influential pairs ("leave-one-out" LOO) and alternate samples/windows (Santos Silva and Tenreyro, 2011). For staggered DiD, robustness checks usually include changing which entry groups (cohorts) and time windows are used, treating the years before entry differently to account for anticipation, testing fake (placebo) treatment dates, and using weighting methods that prevent large countries from dominating the results (Callaway and Sant'Anna, 2021). For dynamic-panel GMM, good practice focuses on keeping the instrument set small, comparing difference GMM with system GMM, and checking how sensitive the results are to different choices of lag length (Blundell and Bond, 1998).

This thesis follows that general pattern. Bilateral trade is analyzed using a gravity model estimated by PPML with appropriate fixed effects; macroeconomic variables such as inflation and GDP per capita are studied using modern DiD/event-study tools for staggered treatment timing and complemented by system-GMM benchmarks that control for persistence and possible reverse causality from macroeconomic variables to policy. Because these econometric choices are standard in the literature and aimed at the same identification issues emphasized by earlier work—multilateral resistance, selection into agreements, and persistence—they provide a flexible framework in which the exact implementation (for example, choice of specific DiD estimator or GMM lag structure) can be refined without changing the overall interpretation of the empirical results.

Monetary unions and optimum currency areas

A related strand of literature studies the conditions under which it is beneficial for countries to share a common currency. The classic "optimum currency area" (OCA) models by Mundell (1961) and McKinnon (1963) emphasize several key criteria: the degree of labor and capital mobility across borders, the openness and diversification of the economy, the similarity of business-cycle shocks and the presence of fiscal-transfer mechanisms. If countries face similar shocks and adjust quickly, a common monetary policy can work well. However, if shocks are very asymmetric and adjustment is slow, the loss of an independent exchange rate can be costly. Later work connects these ideas more directly to trade and integration. Frankel and Rose (1998) show that higher trade integration itself may make business cycles more correlated over time, so that some OCA criteria are endogenous: countries may become "more suitable" for a currency union after they integrate. Bayoumi and Eichengreen (1994, 1997) use VAR and OCA-type exercises to compare shock structures across regions and conclude that Europe looks more like a potential currency area than, for example, many parts of the developing world. Alesina and Barro (2002) model currency unions in a more formal way, highlighting trade links and inflation preferences as determinants of who benefits from a common currency.

For this thesis, the OCA literature mainly serves as a conceptual background. The empirical work does not attempt to estimate a complete OCA model for Central Asia, but it uses some of the same variables (trade intensity, growth, inflation behavior) to ask whether existing regional agreements and external openness are associated with conditions that would be favorable or unfavorable for a potential monetary union. In other words, instead of claiming that CA already forms an "optimum" currency area, the analysis asks whether trade and macro patterns are moving in a direction that is more or less compatible with such a union.

Monetary integration in the Eurasian and Central Asian context

Debates on monetary integration in Eurasia have generally evolved alongside broader efforts toward economic cooperation. The most widely examined reference point in this field remains the European Economic and Monetary Union (EMU), which joins a common market with a unified currency and a shared central bank. A substantial empirical literature assesses how the EMU influenced member economies in terms of trade, output growth, inflation, and business-cycle co-movement (for example, Frankel and Rose, 1998; Bayoumi and Eichengreen 1997). These experiences often serve as an external benchmark when considering whether similar forms of monetary deepening might be feasible in other world regions, including Central Asia. The institutional trajectory across the post-Soviet space has been considerably less uniform. Despite the fact that regional platforms such as the Commonwealth of Independent States (CIS) and, later, the Eurasian Economic Union (EAEU) were designed to stimulate closer economic ties, neither has resulted in a full monetary union. Prior research, including Vinokurov and Libman (2012) and Dragneva and Wolczuk (2012), emphasizes the coexistence of overlapping regional arrangements, unequal bargaining power among

members, and politically driven motives behind rule coordination. All these factors complicate long-term commitments to monetary integration.

For the Central Asian economies specifically, several structural features shape the discussion. These include strong reliance on commodities, high sensitivity to external shocks (e.g., energy-price movements, fluctuations in Russian demand, or remittance inflows), and the ongoing development of domestic economic institutions. Empirical findings indicate that inflation and growth differ substantially across countries and over time (Incaltarau et al., 2022; Yorucu, 2013), while economic ties with Russia, China, and the EAEU produce uneven effects across sectors. Against this backdrop, the present thesis does not seek to deliver a prescriptive statement on whether a CA monetary union should or should not be established. Rather, it employs gravity models, staggered DiD/event-study designs, and dynamic-panel approaches to document how existing patterns of trade agreements and openness relate to trade performance, inflation, and growth, and consequently to assess what these relationships may imply for the long-run practical viability of deeper monetary integration.

Synthesis and contribution

The strands of literature reviewed above point in a common direction but leave several gaps for the Central Asian case. Gravity studies emphasize that the trade effects of regional agreements and WTO membership are context-dependent and must be estimated in specifications that respect multilateral resistance and dynamic selection into agreements (Baier and Bergstrand, 2007; Head and Mayer, 2014; Yotov et al., 2016). Convergence and monetary-union analyses highlight that income and inflation paths may follow club-specific dynamics rather than a single global trajectory, particularly in regions with strong external shocks and uneven structural reforms (Phillips and Sul, 2007, 2009; Incaltarau et al., 2022; Yorucu, 2013). Recent econometric work on staggered treatments and dynamic panels warns that naive two-way fixed-effects models can obscure treatment timing and persistence, and advocates designs that transparently separate within-pair variation, cohort-specific effects and dynamic adjustment (Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Roodman, 2009). For Central Asia, existing empirical contributions typically focus either on trade flows or on growth and convergence, but rarely integrate both dimensions within a single framework centered on regional agreements. Gravity-type studies document that geography, landlockedness and infrastructure constraints remain major determinants of trade, and that CIS and EAEU effects are heterogeneous and often intertwined with Russian and Chinese demand (Grafe, Raiser and Sakatsume, 2008; Mazhikeyev, Edwards and Rizov, 2015; Mukhamediyev and Khitakhunov, 2017; Cieślik and Gurshev, 2022, 2024). Convergence-oriented work shows that growth and income dispersion in the region have been shaped by commodity dependence and external shocks (Incaltarau et al., 2022; Yorucu, 2013), while institutional analyses stress the political-economy complexity of overlapping arrangements such as the CIS, EAEU and Shanghai Cooperation Organization (Dragneva and Wolczuk, 2012; Vinokurov and Libman, 2012; Krapohl and Vasileva-Dienes, 2020). However, there is

relatively little evidence on how these agreements jointly relate to both trade and macro indicators in a way that is directly informative for potential monetary integration.

This thesis contributes to the literature in three ways. First, it provides a focused gravity assessment of CIS, EAEU and WTO membership for the five CA economies, estimated with state-of-the-art PPML and high-dimensional fixed effects on a long panel of bilateral trade flows. Second, it extends the regional integration literature by applying modern staggered DiD/event-study methods to macroeconomic indicators such as CPI inflation and GDP per capita, in order to study whether CIS accession is associated with more stable prices and income dynamics, while explicitly acknowledging the small N limitations of the Central Asian panel. Third, it benchmarks these DiD results against dynamic-panel system-GMM estimates, thereby linking the gravity and institutional-integration debates to the broader literature on persistence and convergence in macroeconomic panels. Conceptually, the thesis adopts the convergence-club perspective of Phillips and Sul (2007, 2009): instead of testing for global "β" or "σ"-convergence, it asks whether membership in specific trade agreements is associated with patterns of trade and inflation that are more or less compatible with the long-run practical viability of a Central Asian monetary union.

Data

This thesis combines a directed bilateral trade panel for the gravity analysis (Pillar 1) and a country–year macroeconomic panel for the policy evaluation (Pillar 2). The analysis focuses on five Central Asian economies—Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—using annual data for 1995–2024. Variable definitions used in each estimator and all model equations are provided in the Methodology section; this Data section documents sources, coverage, and final estimation samples.

(i) Trade flows

Bilateral trade flows are drawn from the IMF Direction of Trade Statistics (DOTS), using annual series for goods exports and imports. The trade dataset is organized in directed exporter–importer–year format (*i,j,t*) with exporter and importer coded as ISO3-style country codes (KAZ, KGZ, TJK, TKM, UZB). The estimation sample includes all 20 directed dyads among the five countries observed over 30 years, yielding a balanced panel of 600 exporter–importer–year observations.

The dependent trade measure used in Pillar 1 is the bilateral trade value X_{ijt}in levels, corresponding to exporter i's FOB exports to importer $j$in year t. Zero-valued flows are retained (consistent with PPML estimation), and the final estimation dataset contains no missing values for X_{ijt}. Pair–year indicators capturing joint institutional membership (e.g., joint WTO and joint EAEU status) are used as policy exposures in the gravity specifications. CIS pair-year participation is constructed from country–year CIS membership for each partner. Where memberships overlap strongly over time in this small sample, the gravity specifications use non-overlapping exposure definitions

for interpretability; the exact definitions used in the PPML regressions are stated in the Pillar 1 methodology subsection.

(ii) Macroeconomic variables

Macroeconomic variables are obtained from the World Bank World Development Indicators (WDI). The country–year panel covers the same five countries over 1995–2024 and is balanced with 150 observations (5 countries × 30 years). The main macro outcomes used in Pillar 2 are (i) GDP per capita (current US$) (used in logs in parts of the analysis) and (ii) CPI inflation (annual %) (used as the primary outcome for the staggered DiD/event-study analysis). Additional macro series used for descriptive statistics and robustness specifications include net FDI inflows (% of GDP), exports and imports of goods and services (current US$), total GDP (current US$), trade openness (trade as % of GDP), and population. For the inflation analysis, the thesis uses a winsorized inflation series for estimation; its definition and motivation are provided in the methodology section.

(iii) Policy and treatment variables (CIS, EAEU, WTO)

Policy exposure is coded using annual country–year membership indicators for: CIS FTA participation, EAEU membership, and WTO membership. WTO membership is aligned with WTO accession/member documentation. CIS FTA participation is referenced to the CIS Free Trade Area agreement as recorded in the WTO Regional Trade Agreements (RTA) Database. EAEU membership is referenced to the Eurasian Economic Union and related accession documentation. For staggered DiD/event-study designs, treatment timing is defined as each country's first year coded as treated for the relevant policy; countries that do not join within the sample window are treated as never-treated for that policy.

Methodology

Pillar 1 — PPML gravity model

Bilateral trade among the five Central Asian (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) economies is studied using annual data for 1995—2024.

Core variables:

• $\boldsymbol{X_{val}}$ − bilateral trade value from i to j (dependent variable in PPML).

• $\boldsymbol{pair\_wto_{ijt}}$ — 1 if both countries (pair) are World Trade Organization (WTO) members in year t.

• $\boldsymbol{pair\_eaeu_{ijt}}$ — 1 if both countries (pair) are Eurasian Economic Union (EAEU) members in year t.

• $\boldsymbol{cis\_only_{ijt}}$ — 1 if both countries (pair) are only member of the Commonwealth of Independent States (CIS) and not yet jointly WTO/EAEU.

The reason CIS (*CIS_only*) is different from other two variables (pair_wto and pair_eaeu) is that CIS overlaps heavily with EAEU/WTO in the sample. Many dyad-years (pair) that are in CIS FTA, are also joint EAEU or joint WTO later on. When a broad pair_cisfta was included together with pair_eaeu and pair_wto, the same policy exposure was double-counted and created severe multicollinearity problems. For that reason, a cis_only variable was constructed, which captures a pure CIS effect in non-overlapping cases.

PPML baseline model:

$$\boldsymbol{E}\left[\, \boldsymbol{x_{ijt}} \,|\cdot\right] = \boldsymbol{exp}\left(\boldsymbol{\beta_1}\,\mathbf{pair\_wto}_{\boldsymbol{-ijt}} + \boldsymbol{\beta_2}\,\mathbf{pair\_eaeu}_{\boldsymbol{ijt}} + \boldsymbol{\beta_3}\,\mathbf{cis\_only}_{\boldsymbol{ijt}} + \boldsymbol{\theta_{ij}} + \boldsymbol{\delta_{it}} + \boldsymbol{\gamma_{jt}}\right),$$

- where "·" denotes all controls and fixed effects included on the right-hand side of the expression;
- x_{ijt} or $X_{val}$is bilateral trade from i to j in year t;
- θ_{ij} are pair fixed effects (absorbs distance, common border, language and any time-invariant bilateral factor);
- δ_{it} are export-year fixed effects (absorbs exporter's GDP, exporter shocks and exporter's overall trading environment);
- γ_{jt} are importer-year fixed effects (absorbs importer's GDP, importer shocks and importer's overall trading environment);

Moreover, "exp (·)" denotes the exponential function which is standard in PPML and ensures that predicted trade flows are non-negative and makes policy coefficients naturally interpretable as proportional (multiplicative) changes.

Results and interpretation

Table 1: Incidence rate ratios (IRR=exp(β)) from PPML gravity estimates with bilateral trade value x_{ij}, defined as exports from country i to country j in year t.

Variable	Baseline A no trends (1)	Baseline B +pair trends (2)	WTO only (3)	EAEU only (4)	CIS only (5)
pair_wto	3.044** (1.154, 8.032) $p = 0.025$	2.105*** (1.384, 3.201) $p < 0.001$	9.195*** (4.388, 19.266)	–	–
pair_eaeu	0.634 (0.305, 1.321) $p = 0.224$	7.132*** (2.675, 19.011) $p < 0.001$	–	1.552 (0.538, 4.474)	–
cis_only	0.178*** (0.056, 0.565) $p = 0.003$	0.295** (0.117, 0.742) $p = 0.010$	–	–	0.074*** (0.041, 0.133)
Observations	600	600	600	600	600
Pseudo-R^2	0.954 (1)	0.965 (2)	0.953 (3)	0.942 (4)	0.953 (5)

Notes: IRR values greater than 1 indicate trade-enhancing effects; values below 1 indicate trade-reducing effects. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. 95% confidence intervals (IRR scale) are in parentheses.

PPML with a log link was estimated with dyad (pair) fixed effects and exporter-/importer-year fixed effects. Coefficients β are obtained on the log scale. For interpretation, effects are reported as incidence rate ratios (IRR), defined as IRR = exp (β). An IRR greater than 1 indicates a multiplicative increase in expected bilateral trade, an IRR of 1 indicates no change, and an IRR below 1 indicates a decrease. Because the coefficients are reported as IRR, the null effect corresponds to IRR = 1; a coefficient is statistically insignificant when its confidence interval includes 1, even though it never includes 0 on the IRR scale. Reported 95% confidence intervals and p-values are computed for the log-coefficients and then mapped to IRR by exponentiation. Columns one and two are the two main "baseline" gravity models and both include the same fixed effects (pair fixed effects and exporter-year/importer-year fixed effects). The difference is that Baseline A does not allow each country-pair to have its own gradual trend over time. Baseline B (with pair trends) does allow that: it considers the possibility that trade between a given pair was already slowly rising (or falling) over the years for reasons unrelated to agreements (for example, improving transport links, business ties, or general normalization). In other words, Baseline B asks whether WTO/EAEU/CIS are associated with extra changes in trade on top of the pair's own underlying trend. Columns three to five are "one-policy" models. For example, "WTO only" means the gravity model is estimated with the WTO joint-membership indicator

as the only policy variable (plus the same fixed effects), and the same logic applies to "EAEU only" and "CIS only". These columns are shown to make it easy to see what each agreement is associated with when it is considered on its own.

The PPML estimates indicate that joint WTO membership is robustly associated with higher bilateral trade in the preferred specification with pair-specific trends (Table 1). Conditional on the fixed effects, the IRR of 2.105 implies that trade between two WTO members is, on average, about twice as large as trade between otherwise comparable non-member pairs. WTO results are stable across columns. Across specifications, in both joint-policy and single-policy models, the WTO coefficient remains positive and statistically significant. One plausible interpretation is that WTO membership increases bilateral trade by making market access more predictable and reducing trade-policy uncertainty. WTO research treats trade-policy uncertainty as a barrier to trade, and structural-gravity evidence also finds a positive and statistically significant effect of WTO membership on trade between member countries (Osnago, Piermartini, and Rocha, 2015; Larch et al., 2019). In this thesis, these channels are discussed only as plausible economic mechanisms behind the estimated reduced-form coefficient, not as separately identified causal effects. By contrast, CIS-only dyads are associated with substantially lower trade, while trade is higher for the same pair once it additionally overlaps with WTO/EAEU membership. For EAEU, the estimates are highly sensitive to specification and rely on a very small treated sample (essentially one main pair, Kazakhstan–Kyrgyzstan), so they are not treated as robust evidence and are reported in the table for completeness only. Overall, the pattern is in line with rules-based integration via WTO (and possibly EAEU) being associated with higher trade, whereas CIS-only coverage coincides with lower bilateral trade.

Pillar 2 (A)— CSDID (Callaway–Sant'Anna's Difference-in-Differences)

Difference-in-Differences (DiD) analysis is implemented using Callaway and Sant'Anna's (2021) cohort-specific DiD estimator (CSDID) for the same five Central Asian economies covering 1995—2024. The main indicator is annual CPI inflation. It is crucial to highlight that annual CPI inflation is winsorized (inflation_w) at the 1st and 99th percentiles in order to cap extreme outliers (transition-period spikes such as acquiring independence after the collapse of the Soviet Union) so that a small number of unusually large observations do not drive the DiD/event-study estimates in this small five-country panel. In other words, observations below p1 = 0.75% are set to 0.75%, and observations above p99 = 313.69% are set to 313.69%, while all other observations remain unchanged. Note that all DiD results for inflation are based on inflation_w; the raw inflation series is used only for descriptive plots. In addition to that, as a robustness check, the baseline specification examining the effect of CIS on CPI inflation specification is re-estimated on a restricted post-2000 subsample (2000‑2024), where pre-periods are cleaner and less dominated by transition spikes. The results remain qualitatively unchanged under this restriction, indicating that the main findings are not driven by the turbulent late-1990s. Furthermore, several diagnostic and complementary checks were carried out: (i) on log GDP per capita (ln_gdp_pc), (ii) placebo-timing

tests, (iii) leave-one-out (LOO) influence checks, and (iv) complementary TWFE models with wild-cluster bootstrap p-values appropriate for the few-cluster setting. Treatment timing was encoded via gvar(·). For CIS, gvar(cis_year) was used in the main design, with placebos gvar(cis_year_lead3) and gvar(cis_year_fut5). For EAEU, placebo designs employed gvar(eaeu_year_lead3) and gvar(eaeu_year_fut5); "never-treated" controls were used where appropriate (countries that never joined EAEU). Moreover, group×time effects (ATT[g,t]) were estimated and then aggregated to an overall Average Treatment Effect on the Treated (ATT).

Results and interpretation

Table 2: Average treatment effect on the treated (ATT) of CIS accession on annual CPI inflation (inflation_w), 1995–2024.

Outcome	Estimator	Sample	ATT	SE	p-value
inflation_w	CSDID (csdid)	1995–2024	-1.696	0.567	0.003

Notes: ATT is estimated using the Callaway–Sant'Anna staggered DiD estimator (CSDID). Standard errors are clustered at the country level.

Table 2 shows that CIS accession is associated with lower annual inflation in treated countries. The CSDID estimate (ATT) is -1.696 percentage points with a standard error of 0.567 and a (normal) p-value of 0.003, implying a statistically precise effect. Interpreted plainly, after CIS entry, a treated country's inflation rate is about 1.7 percentage points lower per year than it would have been in the absence of CIS, relative to the contemporaneous path of non-treated countries (95% CI: approximately -2.81 to -0.58 percentage points). A similarly cautious interpretation is that CIS accession may reduce intra-regional goods-trade frictions (especially for tradables), which can ease supply constraints and strengthen import competition. At the same time, inflation in these economies still depends heavily on exchange rates, food and energy prices, and domestic macroeconomic policy. This interpretation is institutionally plausible because the CIS FTA text (Articles 2–3) limits customs duties in mutual trade and restricts quantitative trade barriers (subject to exceptions), while recent IMF evidence for the Caucasus and Central Asia highlights the strong role of external factors and exchange-rate pass-through in inflation dynamics (CIS FTA Agreement, 2011; Atamanchuk et al., 2025). The thesis does not identify these channels separately.

Diagnostic and complementary checks

Table 3: Event-study summary for CIS accession with annual CPI inflation (inflation_w) as the response variable.

Statistic	Estimate	SE	z	p-value	95% CI	
Pre avg	-0.1452	0.8878	-0.16	0.870	-1.885	1.595
Post avg	-1.8236	0.8744	-2.09	0.037	-3.537	-0.110
Lead t-4 (Tm4)	5.4185	0.2777	19.51	0.000	4.874	5.963

Notes: Estimates come from the Callaway–Sant'Anna (2021) event-study for staggered treatment timing. "Pre avg" is the average of pre-treatment coefficients. "Post avg" is the average post-treatment effect. "Lead t-4 (Tm4)" is the coefficient four periods before treatment. Standard errors are clustered at the country level.

Table 3 uses the event-study to check timing and pre-trends. The average of all pre-treatment years is close to zero and statistically insignificant, which supports parallel trends on average. After CIS entry, the mean post-treatment effect is -1.82 pp and statistically significant at conventional levels. In other words, inflation is about 1.8 percentage points lower on average in the post-treatment years. One individual lead shows an outlier: t-4 = +5.42 pp ($p<0.001$) meaning that four years before a country joined the CIS (t-4), its inflation was about 5.4 percentage points higher than the control group in that year, and the model estimates that difference very precisely ($p<0.001$). Given the tiny sample and changing group composition, this spike suggests that some CIS-related adjustment in inflation may already be taking place before formal entry. It therefore weakens a strict parallel-trends interpretation and implies that the post-2000 ATT should be interpreted with caution, even though the other leads are near zero and the first clearly negative effect appears around t+2 (≈-1.55 pp). This pattern does not contradict findings for EU accessions, where macro variables may already respond in the pre-accession phase when convergence or stability criteria are applied. Overall, there is no clear pre-trend, followed by a sustained decline in inflation after CIS accession.

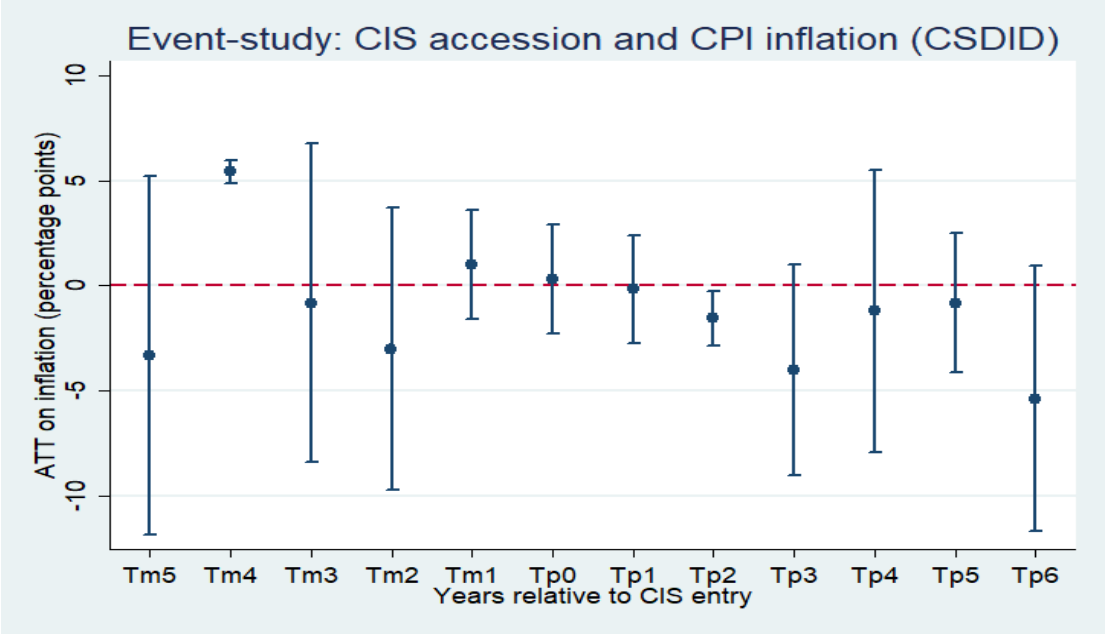

Figure 5. *Event-study estimates of CIS accession on CPI inflation (CSDID)*

Figure 5 visualizes the CSDID event-study coefficients for CIS accession and CPI inflation. Most pre-treatment coefficients are close to zero and statistically imprecise, in line with the small and insignificant average pre-effect reported in Table 3, although the estimate at event time t−4 is positive and statistically significant. After the CIS entry year, the coefficients are generally negative and remain below zero for several years, indicating lower inflation in the post-accession period for treated countries. Confidence intervals vary across event times because the composition of treated and comparison observations changes over the event window, so the figure supports a negative CIS–inflation association but also underlines the need for cautious interpretation.

Table 4: "Leave-one-out" CSDID ATT of CIS accession on annual CPI inflation ($inflation\_w$)

Country omitted	**ATT**
KAZ	−1.7149
KGZ	−1.9793
TJK	−1.0951
TKM	+1.7206
UZB	−2.0123

Notes: "Leave-one-out" results report the ATT re-estimated after excluding one country from the sample.

This "leave-one-out" (LOO) check reruns the CSDID model estimating the effect of CIS on inflation each time after removing a single country. Each row reports the re-estimated ATT. The sign flip when Turkmenistan (TKM) is omitted indicates that TKM is influential for the pooled estimate. That is to say, when Kazakhstan, Kyrgyzstan, Tajikistan or Uzbekistan is dropped, the ATT remains negative and of

similar magnitude to the baseline, indicating that the estimated CIS-related reduction in inflation is not driven solely by any one of those four countries. However, when Turkmenistan is dropped, the ATT turns positive, which shows that this country has substantial leverage on the pooled result.

Table 5: Placebo CSDID checks for CIS accession where the response variable is either annual CPI inflation (inflation_w) or log GDP per capita (ln_gdp_pc).

Design	Outcome	gvar	ATT	SE	z	p-value
CIS lead -3	inflation_w	cis_year_lead3	-4.1276	1.9157	-2.15	0.031
CIS future +5	inflation_w	cis_year_fut5	-1.4317	4.3653	-0.33	0.743
EAEU lead -3	ln_gdp_pc	eaeu_year_lead3	-0.1068	0.1057	-1.01	0.313
EAEU future +5	ln_gdp_pc	eaeu_year_fut5	-0.0012	0.0182	-0.06	0.948
EAEU lead -3	inflation_w	eaeu_year_lead3	-3.0658	4.2580	-0.72	0.472
EAEU future +5	inflation_w	eaeu_year_fut5	7.4839	2.0019	3.74	0.000

Notes: Placebo specifications shift the treatment timing backward ("lead -3") or forward ("future +5") to test for spurious pre-trends or artificial post-treatment effects. "gvar" denotes the shifted treatment indicator used in each placebo regression. Standard errors are clustered at the country level.

The CIS placebo with a three-year lead indicates a statistically significant reduction in inflation already before formal CIS entry, so the main CIS effect may be partly anticipated. The CIS placebo with a far future date is statistically null, as desired. For EAEU placebos on log GDP per capita and inflation, most designs deliver statistically null results. However, a placebo with a future EAEU date yields a strong positive effect on inflation despite being set in the future, which is difficult to reconcile with a genuine treatment effect and likely reflects late-period macro shocks interacting with the very limited EAEU treatment sample. As a result, EAEU-related estimates are treated as fragile and not used for causal conclusions.

Table 6: Complementary TWFE regressions with annual CPI inflation ($inflation\_w$) and log GDP per capita (ln(GDPpc)) as response variables. Wild-cluster p-values reported.

Outcome / Specification	Coefficient	SE	Wild-p
Inflation (joint policy TWFE)	21.582	6.426	0.0625
ln(GDPpc) (joint policy TWFE)	-0.205	0.139	0.5625
Inflation (TWFE + country trends)	-48.813	30.282	0.4375
ln(GDPpc) (TWFE + country trends)	0.142	0.169	0.6875

Notes: TWFE models include country and year fixed effects. "TWFE + country trends" additionally includes country-specific linear time trends. "Wild-p" reports wild-cluster p-values based on country-level clustering.

In the joint-policy TWFE regressions (Table 6), the CIS coefficient for inflation is positive and only borderline significant, and its sign even flips once country trends are added. For log GDP per capita, CIS coefficients are small and statistically indistinguishable from zero. Overall, TWFE estimates are unstable across specifications and not statistically reliable with wild-cluster inference; accordingly,

causal interpretation is based on the CSDID results, and TWFE is presented only as a complementary robustness illustration.

Before turning to the dynamic-panel benchmark, it is relevant to mention that the estimates for WTO, EAEU and log GDP per capita were also obtained but are not interpreted in detail. In this five-country panel, identification for WTO and EAEU in the CSDID framework is very weak (almost no never-treated units after 2021 and only a single small treatment cohort for the EAEU), so the resulting cohort- and dynamic effects are imprecise and sensitive to specification. In complementary TWFE robustness checks, coefficients related to WTO, EAEU and log GDP per capita are likewise unstable and not statistically reliable once wild-cluster inference is applied. For this reason, these results are reported only for completeness and are not used as a basis for causal policy conclusions.

Pillar 2 (B)- Dynamic-panel benchmark (System GMM)

To benchmark the panel results against a commonly used approach in the empirical literature, dynamic panel regressions are estimated using system GMM (Generalized Method of Moments) in the sense of Arellano and Bond (1991) and Blundell and Bond (1998). This approach treats the lagged dependent variable as predetermined and addresses potential endogeneity through the use of internal instruments. Given the panel structure of the sample, five countries observed over a relatively long time horizon (1995—2024), instruments for the differenced equation are collapsed and lagged from period t-2 onward, year dummies are included as exogenous controls, and finite-sample corrections are applied.

For log GDP per capita, the model is specified as:

$$\boldsymbol{ln\, y_{it} = \alpha\, ln\, y_{i,t-1} + \beta_1\, WTO_{it} + \beta_2 EAEU_{it} + \beta_3 CIS_{it} + \mu_i + \tau_t + \varepsilon_{it},}$$

where $\boldsymbol{\mu_i\ and\ \tau_t}$ denote country and year effects. For inflation, the dynamic specification takes the form:

$$\boldsymbol{\pi_{it} = \rho\, \pi_{i,t-1} + \beta_1\, WTO_{it} + \beta_2 EAEU_{it} + \beta_3 CIS_{it} + \mu_i + \tau_t + \varepsilon_{it}}$$

with $\boldsymbol{\pi_{it}}$ denoting the annual CPI inflation rate. In both equations WTO, EAEU and CIS are the same policy dummies used in the DiD pillar.

Model adequacy is assessed using the AR(1) and AR(2) tests for serial correlation in the differenced residuals, together with the Hansen test of over-identifying restrictions. The number of instruments is monitored relative to the number of cross-sectional units in order to limit instrument proliferation. While the cross-sectional dimension is limited, this feature affects all panel-based estimators employed in the thesis rather than dynamic specifications alone. With a relatively long time dimension (T = 30), the diagnostic tests remain informative, but the system-GMM results are nevertheless interpreted with caution and treated as a benchmark rather than as the main identification strategy.

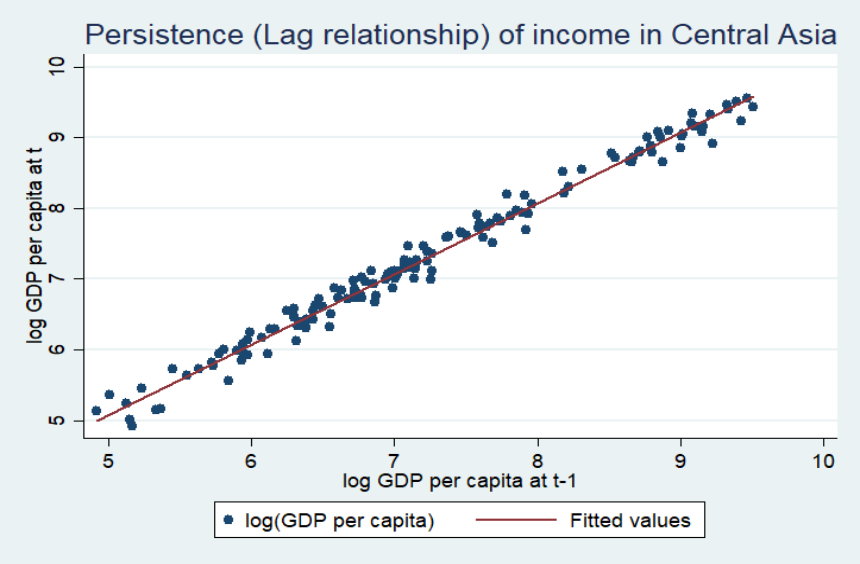

Figure 6. *Log GDP per capita in year t plotted against log GDP per capita in year t-1(Central Asia, 1995—2024)*

Figure 6 plots log GDP per capita in year *t* against its value in year t − 1. The tight clustering of observations around the 45-degree line suggests a strong year-to-year association in log income, which is suggestive high persistence. However, the figure is descriptive and does not identify a specific autoregressive parameter (nor does it provide formal evidence that an AR(1) coefficient is "close to one"). The system-GMM results reported in Table 7, which explicitly include a lagged dependent variable and control for year effects, indicate that much of the variation in GDP per capita is captured by the lag and common shocks. Once this dynamic component and year fixed effects are included, less independent variation remains with which to separately identify WTO, EAEU, and CIS effects on growth. The weaker policy coefficients in the dynamic specification relative to the static DiD results may therefore reflect the inclusion of dynamic adjustment and common shocks, although some caution is warranted given the borderline AR(2) result in the GDP specification.

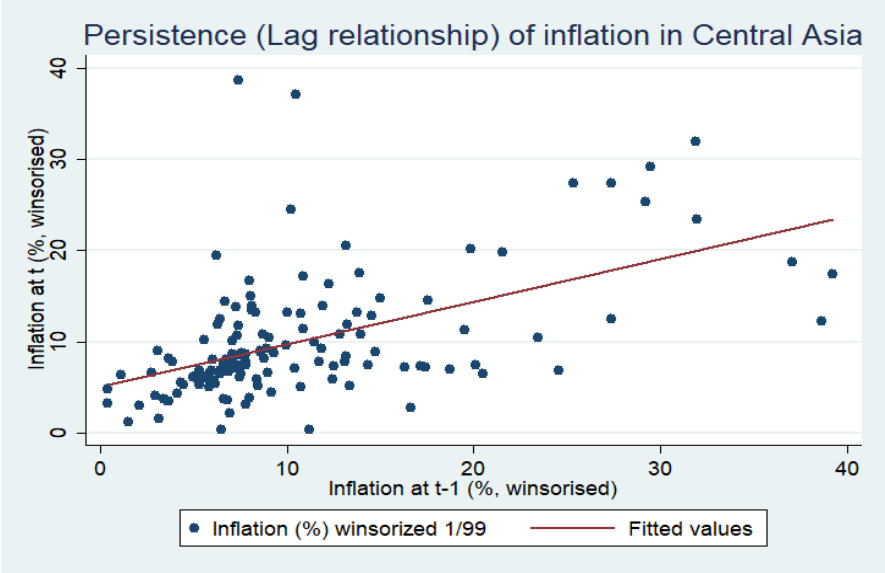

***Figure** 7. CPI inflation in year t plotted against CPI inflation in year $t-1$ (winsorised series)*

Figure 7 plots CPI inflation in year t against its value in year $t-1$ (winsorised at the 1st and 99th percentiles). The scatter shows a positive relationship between current and lagged inflation, although with substantial dispersion. A strong positive relationship in a lag plot is suggestive of persistence in the sense of an AR(1) component, but the figure is descriptive and does not identify a specific autoregressive parameter. This pattern aligns with the dynamic-panel results, where the coefficient on lagged inflation is positive once country and year effects are included.

Taken together, Figures 6 and 7 motivate the use of a dynamic specification and illustrate that macroeconomic indicators in this dataset are strongly influenced by persistence and common shocks. At the same time, the separate identification of policy effects in such a small macro panel is more limited and should be interpreted with caution.

Results and interpretation

Table 7: Dynamic-panel (system-GMM) benchmark with log GDP per capita and annual CPI inflation ($inflation\_w$) as response variables.

	ln(GDP per capita)	**Inflation (%)**
Lagged dependent var	1.010*** (0.004)	0.049* (0.018)
WTO, EAEU, CIS	Omitted (collinear with year FE)	Omitted (collinear with year FE)
Observations	145	145
Countries	5	5
Instruments	60	60
AR(1) p-value	0.032	0.000
AR(2) p-value	0.055	0.458
Hansen p-value	1.000	1.000

Notes: System-GMM estimates follow Arellano–Bover/Blundell–Bond. AR(1) and AR(2) are Arellano–Bond serial-correlation tests; Hansen is the overidentification test. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Standard errors in parentheses.

For log GDP per capita, the system-GMM estimates indicate a very high degree of persistence: the coefficient on the lagged dependent variable is approximately 1.01 and statistically highly significant, suggesting that changes in GDP per capita are small relative to its level. Once this dynamic term and the full set of year dummies are included, the WTO, EAEU and CIS dummies become perfectly collinear with the time effects and are therefore omitted by STATA. As a result, no separate growth effect can be identified for the policy variables within this dynamic specification.

AR(1) behaves as expected and given this borderline AR(2) result, some degree of dynamic misspecification in the GDP equation cannot be ruled out. At the same time, the small number of countries is not a limitation specific to the system-GMM approach but affects all panel estimators employed in this thesis. With a relatively long time dimension (T = 30), the system-GMM results are therefore best viewed as a complementary dynamic benchmark rather than dismissed on mechanical small-sample grounds. The disappearance of policy coefficients in this framework may reflect the dominance of persistence and common shocks, but it cannot be excluded that the corresponding effects identified in the static DiD models are sensitive to specification choice.

For inflation, the system-GMM regression likewise points to a dynamic but largely mean-reverting process, with a small positive coefficient on lagged inflation indicating modest persistence once country and year effects are controlled for. As in the growth equation, the WTO, EAEU and CIS dummies are collinear with the full set of time effects and are therefore omitted by the estimator, implying that inflation dynamics are primarily captured by lagged inflation and common year shocks. The AR(1) test indicates the expected first-order serial correlation, while the AR(2) test does not suggest problematic second-order serial correlation. The Hansen test again yields a very high p-value, which is in line with instrument validity but, given the limited cross-sectional dimension, should be interpreted with caution.

Overall, the structure of the thesis aligns with the idea in Phillips and Sul (2007, 2009) that countries do not automatically converge to a single economic steady state. Instead, convergence patterns may differ across groups depending on structural and institutional conditions. While formal "convergence clubs" are not estimated in this thesis, the underlying logic is similar: rather than assuming convergence purely as a function of time, the analysis examines whether regional trade agreements (CIS, WTO, and EAEU) are systematically linked to macroeconomic performance in Central Asia.

In conclusion, the dynamic-panel benchmark supports an interpretation in which macroeconomic variables are strongly influenced by persistence and common time shocks. With T=30, the usual "short-*T*" critique of dynamic panels is not the central concern here; rather, once lagged dependent variables and full year effects are included, there is little remaining variation to identify separate WTO/EAEU/CIS coefficients. The resulting collinearity and borderline AR(2) statistic in the GDP specification imply that the dynamic results should be interpreted cautiously and treated as a benchmark rather than decisive evidence. At the same time, the disappearance of policy coefficients indicates that growth effects obtained in static specifications may be sensitive to omitted dynamics or common shocks and therefore cannot be ruled out as artifacts. In this sense, the system-GMM results do not contradict the DiD evidence, which points to the most robust policy-related association operating through inflation, where CIS accession is linked to lower inflation in the CSDID estimates. Accordingly, the thesis relies primarily on the DiD pillar for causal interpretation, while the GMM results are reported as a complementary robustness check.

Limitations

This thesis is based on a small macro panel of five countries observed annually over a relatively long horizon. The limited cross-sectional dimension reduces statistical power and constrains the amount of independent variation available for identifying policy effects once country and year effects are included. This small-N constraint affects all panel-based estimators used in the thesis and is not specific to dynamic specifications. A second limitation is that the institutional arrangements overlap in membership and timing. In particular, CIS participation intersects with later WTO and EAEU developments, which creates collinearity concerns and complicates attribution of effects to a single agreement. This overlap motivates the use of a "CIS-only" indicator in the gravity analysis, but it also implies that estimates should be interpreted as associations conditional on the adopted decomposition of policy exposure. Third, staggered DiD designs can be sensitive to anticipation and gradual adjustment. This issue is relevant for WTO accession (which typically follows multi-year reforms) and may also matter for CIS participation, where one event-time lead suggests that inflation dynamics may shift before formal entry. While winsorization of inflation reduces the influence of extreme transition-period outliers, it also implies that the earliest episodes of very high inflation are not modeled in their raw magnitude. Finally, the system-GMM results are presented as a benchmark rather than a primary identification strategy. With T=30, diagnostic tests remain informative, but dynamic specifications are

sensitive to lag structure and instrument choice, and instrument-validity tests can have limited power in small samples. In the GDP equation, borderline AR(2) results indicate that dynamic misspecification cannot be ruled out. For these reasons, the thesis interprets the empirical evidence by triangulation across methods rather than relying on any single estimator.

Future work

While this thesis focuses on aggregate bilateral trade, the underlying mechanisms of integration are likely to differ substantially across products. A natural extension is to move from aggregate bilateral trade to sectoral or product-level flows. Estimating the PPML gravity model on disaggregated trade data at the HS6 level (or, more conservatively, HS4) would show whether the estimated WTO/CIS associations are concentrated in particular product groups (e.g., machinery, food, textiles) rather than reflecting broad-based integration. Such a breakdown would also allow the analysis of heterogeneous effects by product characteristics that are especially relevant in a landlocked region. For example, one could distinguish goods that are highly "border sensitive" because they are perishable, time-sensitive, or require cold chains from goods that are easier to ship and store. If the effects are driven mainly by border-sensitive categories, this would point to logistics and trade facilitation as key mechanisms; if they appear in durable or standardized goods, it would be more in line with rule-based reductions in policy uncertainty and trade costs. More generally, sector-level estimates would help separate changes in trade composition from changes in overall trade volume and would provide a clearer interpretation of how institutional integration operates in Central Asia.

Conclusion

This thesis analyzed whether regional trade agreements are associated with trade integration and macroeconomic indicators in Central Asia. Using annual data for Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan over 1995—2024, the empirical strategy combined a PPML gravity framework for bilateral trade, modern staggered DiD/event-study methods for macroeconomic variables, and a system-GMM benchmark to assess persistence and common shocks.

The gravity results indicate that joint WTO membership is robustly associated with higher bilateral trade in the preferred specification with dyad fixed effects, exporter-year/importer-year fixed effects, and pair-specific trends. In contrast, EAEU estimates are not stable across specifications and are based on very limited treatment variation, so they do not support strong conclusions. The CIS-only indicator is associated with lower trade in the gravity estimates, which is in line with the interpretation that CIS arrangements alone may not generate the same degree of effective market integration as more rules-based frameworks, although this finding should be interpreted with caution given overlap among agreements.

Some country evidence helps illustrate why these estimated patterns are economically plausible, while remaining outside the identification strategy of this thesis. For WTO, Kazakhstan's accession package (effective 30 November 2015) included detailed goods and services commitments, tariff bindings, and rule commitments, and WTO materials describe this package as improving transparency and predictability for trade and investment (WTO, 2015). In Kazakhstan's subsequent Trade Policy Review, the WTO Secretariat also notes progress in trade facilitation, including paperless trade/single-window procedures and implementation of WTO Trade Facilitation Agreement commitments, which is the type of institutional change that can reduce trade costs over time (WTO, 2024). These country developments do not prove the mechanism in my model, but they align with the interpretation that WTO-based rules and predictability can support higher bilateral trade.

In the macroeconomic pillar, the main result concerns inflation. Staggered DiD estimates suggest that CIS accession is associated with lower CPI inflation, and the event-time profile broadly aligns with a post-entry decline. Most pre-treatment coefficients are close to zero and imprecisely estimated, but the t−4 lead (four years before entry) is positive and statistically significant. This may reflect anticipation or changes in composition/controls, so the post-entry pattern should be interpreted with caution. For GDP per capita, results are weaker and not robust across specifications, reflecting both strong persistence in income dynamics and limited identifying variation in this small panel once fixed effects are included.

A cautious interpretation of the CIS inflation finding is that CIS-related trade integration may have reduced intra-regional goods-trade frictions, which could ease supply constraints and strengthen import competition in tradables markets. This interpretation is institutionally plausible because the CIS FTA framework limits customs duties in mutual trade and restricts quantitative barriers, but it remains outside the identification strategy of this thesis (CIS Free Trade Area Agreement, 2011). At the same time, IMF evidence for Central Asia shows that inflation is strongly shaped by external factors — especially food prices, exchange rates, and exchange-rate pass-through (Atamanchuk et al., 2025). Country reports are in line with this broader picture: in Kazakhstan, disinflation has been linked to lower food prices, exchange-rate appreciation, and monetary tightening, while in Tajikistan lower food import prices and currency appreciation also contributed to lower inflation (IMF, 2025). Taken together, this suggests a qualified interpretation: CIS-related integration may have contributed, but observed inflation dynamics also reflect broader external-price and macro-policy forces.

The dynamic benchmark reinforces these conclusions in a disciplined way. Macroeconomic indicators appear strongly shaped by persistence and common shocks. In the GDP system-GMM equation, policy dummies are omitted due to collinearity with time effects once a highly persistent lag structure is included, which illustrates how limited independent variation remains in a fully dynamic setting. At the same time, the borderline AR(2) diagnostic implies that dynamic misspecification cannot be

excluded. If policy effects visible in static specifications disappear in the dynamic setting, the static estimates may be artifacts; however, given the AR(2) results, the dynamic specification is also not definitive.

Taken together, the evidence suggests that trade agreements in Central Asia are more clearly linked to trade integration and price stabilization than to precisely estimated growth accelerations in aggregate annual data. From the perspective of deeper economic integration, this distinction matters: improvements in nominal stability may be detectable even when growth effects are difficult to identify with a small macro panel. Future work could extend the analysis using sectoral trade data, alternative measures of integration intensity, and designs that better separate overlapping institutional arrangements and anticipatory reform dynamics.

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Appendix

Replication and computational details

A.1 Computing environment and software

All results are reproducible in Stata using the accompanying do-files for Pillar 1 (PPML gravity), Pillar 2 A (staggered DiD/event study and robustness), and Pillar 2B (dynamic-panel benchmark). The empirical analysis and replication were executed in Stata 14 on a Windows environment; replication is therefore recommended using Stata 14 with the package versions listed below.

A.2 User-written commands and their roles

Replication relies on the following user-written Stata commands (installed from SSC as needed):

- ppmlhdfe (with dependencies reghdfe and ftools) for PPML gravity with high-dimensional fixed effects.
- csdid for staggered DiD/event-study estimation in the Callaway & Sant'Anna framework.
- winsor2 to winsorize CPI inflation at the 1st and 99th percentiles (creating inflation_w).
- boottest for wild cluster bootstrap inference with few clusters (country-level clustering).
- estout / esttab / eststo for publication-ready regression tables (RTF).
- coefplot for event-study coefficient plots and confidence intervals.
- xtabond2 for system-GMM dynamic-panel benchmark estimation (Pillar 2B), reporting AR(1)/AR(2) and Hansen diagnostics.

A.3 Input data files and common cleaned dataset

Replication uses two primary inputs:

1. Bilateral trade panel (Pillar 1)
   A long-format Excel file containing annual directed trade flows for the five Central Asian economies (exporter exp, importer imp, year, and trade value trade_val, renamed to x_val), together with pair-year institutional indicators.
2. Macroeconomic and policy panel (Pillar 2 / Pillar 2B)
   An Excel file containing annual country-year macro variables (e.g., GDP per capita, CPI inflation, trade openness, GDP, exports/imports, population, FDI) and country-year institutional membership indicators for CIS, EAEU, and WTO.

A.4 Constructed identifiers and key derived variables

A.4.1 Pillar 1 (PPML) fixed-effect identifiers and clustering

To implement a structural-gravity specification with appropriate absorption of multilateral resistance and one-sided macro shocks, the following identifiers are constructed:

- fe_pair: directed dyad fixed-effect ID (one ID per exporter→importer pair).
- fe_expy: exporter×year fixed-effect ID.
- fe_impy: importer×year fixed-effect ID.
- fe_pair_undir: undirected dyad ID used for clustering (A–B ≡ B–A), ensuring robust inference under pairwise correlation across directions.

A.4.2 CIS pair-year exposure and the non-overlap indicator (Pillar 1)

CIS pair-year exposure is constructed from country-year CIS membership for each partner:

- pair_cisfta_year = 1 if both exporter and importer are CIS participants in year *t*.

Because CIS participation overlaps substantially over time with later WTO/EAEU joint membership in this small intra-regional sample, the analysis defines a non-overlapping CIS exposure indicator:

- cis_only = 1 if pair_cisfta_year = 1 and the pair-year is not jointly WTO and not jointly EAEU.

This avoids double-counting overlapping policy exposure and improves interpretability when multiple institutional indicators enter the same PPML regression.

A.4.3 Macro outcomes and transformations (Pillar 2 / Pillar 2B)

- ln_gdp_pc = ln(gdp_pc) is constructed for strictly positive GDP per capita values.
- inflation_w is defined as CPI inflation winsorized at the 1st/99th percentiles for estimation.

Consistency rule used throughout the thesis:
inflation_w always refers to the winsorized inflation series. If any robustness exercise uses raw inflation, it is explicitly labeled inflation (not inflation_w) to avoid confusion.

A.4.4 Staggered-treatment timing variables (Pillar 2)

First-treatment (cohort) years are generated as the earliest year in which a country is coded as a member/participant:

- wto_year, cis_year, eaeu_year, with 0 indicating never-treated within 1995–2024.

These cohort-year variables are used as gvar(·) inputs for csdid.

A.5 Pillar 1 estimation (PPML gravity)

Baseline gravity specifications are estimated via ppmlhdfe:

- Dependent variable: x_val (bilateral exports in levels).
- Policy regressors: cis_only, pair_eaeu, pair_wto_both.
- Fixed effects: fe_pair, fe_expy, fe_impy.
- Inference: clustering by undirected dyads (vce(cluster fe_pair_undir)).

Two main PPML specifications are reported:

1. Baseline PPML (no pair trends) with dyad FE and exporter-year/importer-year FE.
2. PPML with linear pair trends, allowing each dyad to follow its own linear trend via interactions of dyad FE with a centered time index.

Coefficients are reported as multiplicative effects using exponentiated transformations (eform), which is standard for PPML.

Before estimation, the scripts implement routine integrity checks (no duplicate dyad-years; non-negativity of the dependent variable; binary policy indicators).

A.6 Pillar 2 estimation (staggered DiD/event study + robustness)

The main policy evaluation uses Callaway & Sant'Anna's staggered DiD estimator via csdid:

- Panel: country_id (unit) and year (time).
- Treatment timing: gvar(wto_year), gvar(cis_year), gvar(eaeu_year).
- For policies with clear never-treated units (e.g., EAEU in this sample), never is used to define the comparison group.
- Inference: clustering at the country level.

Dynamic effects are presented using estat event with a pre/post window, and a joint pre-trend diagnostic is implemented by testing lead coefficients.

Robustness and diagnostic procedures

To address identification and inference challenges in a small (N=5) country panel, the replication includes:

1. Placebo timing tests shifting treatment dates (lead and "future" placebos) to probe spurious timing/anticipation.
2. Leave-one-out (LOO) influence checks re-estimating ATT while omitting each country in turn.
3. Complementary TWFE models (country FE + year FE) with wild cluster bootstrap p-values using boottest. Wild bootstrap uses 9,999 replications with fixed random seeds (reported in code) for reproducibility.

4. TWFE with country-specific linear trends as a sensitivity test for differential secular trends.
5. Restricted-window robustness (post-2000 subsample) for CIS→inflation to reduce the influence of early transition volatility on pre-period dynamics.

Tables are exported using esttab (RTF), and event-study figures are produced using coefplot.

A.7 Pillar 2B benchmark (dynamic-panel System GMM)

As a complementary benchmark addressing persistence in macro outcomes, Pillar 2B estimates dynamic specifications for:

- ln (GDP per capita)with a lagged dependent variable L. And "L" denotes the one-year lag of the variable (i.e., the value in year $t-1$). ln (GDP per capita) and
- CPI inflation with $L.$ inflation (using the same inflation definition as in Pillar 2).

Estimation uses the Arellano–Bover/Blundell–Bond system-GMM estimator implemented via xtabond2:

- Two-step estimation with robust standard errors,
- finite-sample correction (small), and
- a collapsed instrument matrix (collapse) to mitigate instrument proliferation.

Replication reports standard diagnostics: AR(1) p-value, AR(2) p-value, Hansen p-value, and number of instruments.

Inflation consistency (important):
For Pillar 2B, inflation should be taken as inflation_w either by (a) running System GMM directly on panel_clean.dta (preferred, ensures identical winsorization), or (b) applying winsorization inside the GMM script using the same 1/99 rule before estimation. If raw inflation is used as an additional sensitivity check, it is explicitly labeled inflation and not inflation_w.