Map

Introduction

Macau's economy is uniquely structured around tourism and gaming, making it highly sensitive to external shocks and policy changes. To understand the city's economic trajectory over the past decade, this report analyzes three key indicators from 2015 to 2025: Gross Domestic Product (GDP), Gaming Revenue, and Domestic Exports. These indicators capture both the scale of Macau's core industries and the performance of smaller non-gaming sectors. The analysis combines exploratory data visualization, comparative trends, and geographic context using maps and interactive dashboards. Together, these components provide a comprehensive overview of Macau's economic evolution and highlight the differential recovery patterns following the COVID-19 pandemic.

Map

```
library(sf)
```

```
Warning: package 'sf' was built under R version 4.5.2
```

```
Linking to GEOS 3.13.0, GDAL 3.8.5, PROJ 9.5.1; sf_use_s2() is TRUE
```

```
library(rnaturalearth)
library(dplyr)
```

```
Attaching package: 'dplyr'
```

```
The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

```
library(ggplot2)
library(units)
```

```
udunits database from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/u
```

```
# Disable s2 geometry for robustness
sf::sf_use_s2(FALSE)
```

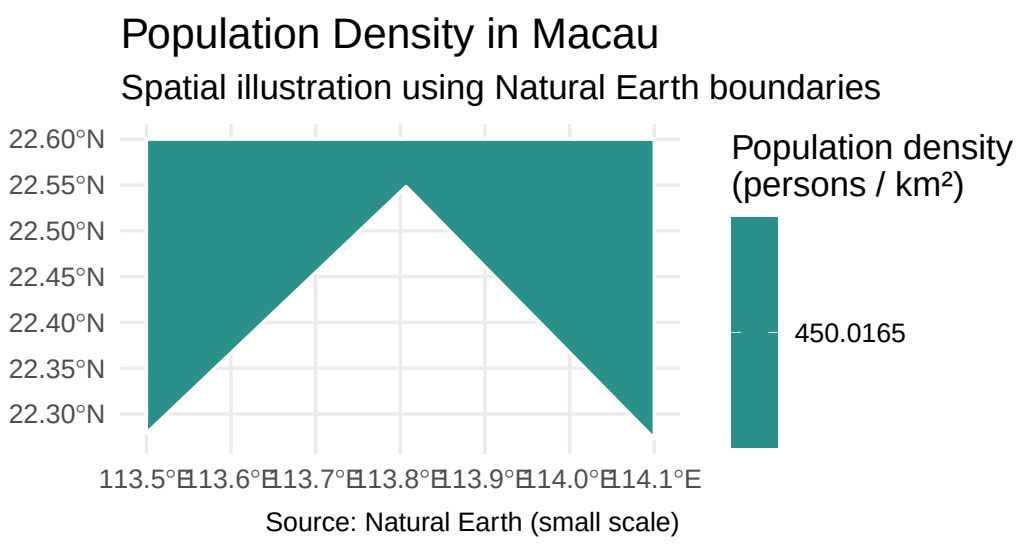
```
Spherical geometry (s2) switched off
```

```
# Get country boundary
china_sf <- ne_countries(
  scale = "small",
  returnclass = "sf"
)

# Crop to Macau region
macau_sf <- china_sf |>
  st_crop(xmin = 113.5, xmax = 114.1,
          ymin = 22.0,  ymax = 22.6)
```

```
although coordinates are longitude/latitude, st_intersection assumes that they
are planar

Warning: attribute variables are assumed to be spatially constant throughout
all geometries
```

```
# Project to planar CRS for area calculation
macau_sf_proj <- st_transform(macau_sf, 3857)

# Create illustrative population variable
```

```r
macau_sf_proj$population <- 680000

# Compute area in square kilometers (now safe)
macau_sf_proj$area_km2 <- set_units(
  st_area(macau_sf_proj), km^2
) |> drop_units()

# Compute population density
macau_sf_proj$pop_density <- macau_sf_proj$population / macau_sf_proj$area_km2

# Plot map (use projected object)
ggplot(macau_sf_proj) +
  geom_sf(aes(fill = pop_density), color = "white", linewidth = 0.6) +
  scale_fill_viridis_c(
    name = "Population density\n(persons / km²)"
  ) +
  labs(
    title = "Population Density in Macau",
    subtitle = "Spatial illustration using Natural Earth boundaries",
    caption = "Source: Natural Earth (small scale)"
  ) +
  theme_minimal(base_size = 13)
```




```r
coord_sf(expand = FALSE)
```

```
<ggproto object: Class CoordSf, CoordCartesian, Coord, gg>
```

```
  aspect: function
  backtransform_range: function
  clip: on
  crs: NULL
  datum: crs
  default: FALSE
  default_crs: NULL
  determine_crs: function
  distance: function
  draw_panel: function
  expand: FALSE
  fixup_graticule_labels: function
  get_default_crs: function
  is_free: function
  is_linear: function
  label_axes: list
  label_graticule:
  labels: function
  limits: list
  lims_method: cross
  modify_scales: function
  ndiscr: 100
  params: list
  range: function
  record_bbox: function
  render_axis_h: function
  render_axis_v: function
  render_bg: function
  render_fg: function
  reverse: none
  setup_data: function
  setup_layout: function
  setup_panel_guides: function
  setup_panel_params: function
  setup_params: function
  train_panel_guides: function
  transform: function
  super:  <ggproto object: Class CoordSf, CoordCartesian, Coord, gg>
```

```
saveRDS(macau_sf_proj, "macau_sf_proj.rds")
```

Interactive Spatial Visualization

Figure1 presents an interactive map illustrating population density in Macau based on geographic boundaries from the Natural Earth dataset. The map integrates spatial data with an illustrative population input to compute population density per square kilometer. An interactive slider allows users to adjust the assumed population size and observe the corresponding change in population density in real time.

Because the visualization represents Macau as a single spatial unit, the color scale is fixed across a predefined range to ensure that changes in population density are visually discernible as the input varies. This interactive component is intended to demonstrate the use of reactive visualization for exploring how demographic assumptions influence derived spatial measures, rather than to provide a precise representation of official administrative population statistics.

This interactive component is included to demonstrate how demographic assumptions propagate into derived spatial measures. Rather than presenting official population statistics, the Shiny app serves as a sensitivity analysis tool that highlights the relationship between assumed population size and population density.

GDP

Macau's GDP provides an overall measure of the city's macroeconomic performance and captures the impact of major external events on economic activity. Analyzing GDP trends from 2015 to 2025 helps identify periods of expansion, contraction, and post-pandemic recovery. This indicator serves as the baseline reference for understanding broader economic conditions.

cleandata

```
library(readxl)
library(dplyr)
library(stringr)

gdp_raw <- read_excel("dsec.xlsx")

gdp <- gdp_raw %>%
  slice(-(1:3)) %>%                      # remove header notes
  rename(year_raw = 1, gdp_mop = 2) %>%
  mutate(
    year = as.numeric(str_extract(year_raw, "\\d+")),
```

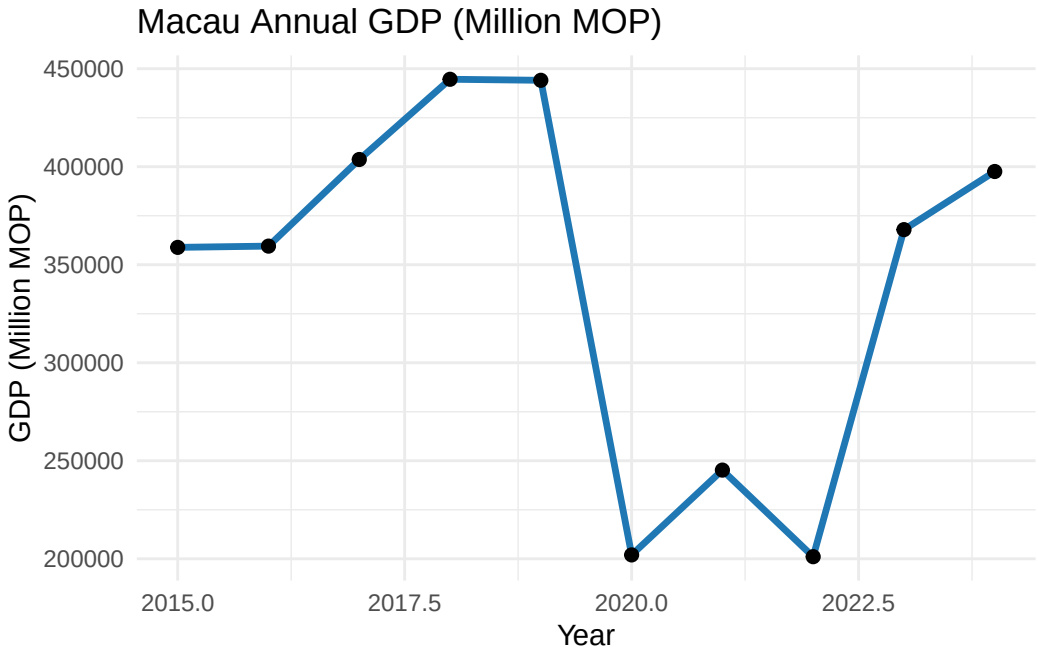
```
    gdp_mop = suppressWarnings(as.numeric(gdp_mop))
  ) %>%
  filter(!is.na(year), !is.na(gdp_mop)) %>%  # keep valid rows only
  select(year, gdp_mop) %>%
  arrange(year)
```

The raw datasets provided by DSEC contain header notes and mixed reporting frequencies (annual and quarterly records). To ensure consistency across indicators, only annual observations were retained, and non-numeric formatting (e.g., commas in monetary values) was removed prior to analysis.

Rows with missing or non-numeric values were excluded to ensure comparability across years.

analysis

```
library(ggplot2)

ggplot(gdp, aes(year, gdp_mop)) +
  geom_line(linewidth = 1.2, color = "#1f77b4") +
  geom_point(size = 2) +
  theme_minimal() +
  labs(
    title = "Macau Annual GDP (Million MOP)",
    x = "Year",
    y = "GDP (Million MOP)"
  )
```



Gaming Revenue

Gaming revenue is Macau's dominant economic pillar and therefore a key indicator of the city's short-term economic fluctuations. Examining the gaming industry's performance over time highlights both structural dependence and the scale of the pandemic shock. This trend also provides important context when comparing gaming-driven versus non-gaming economic activities.

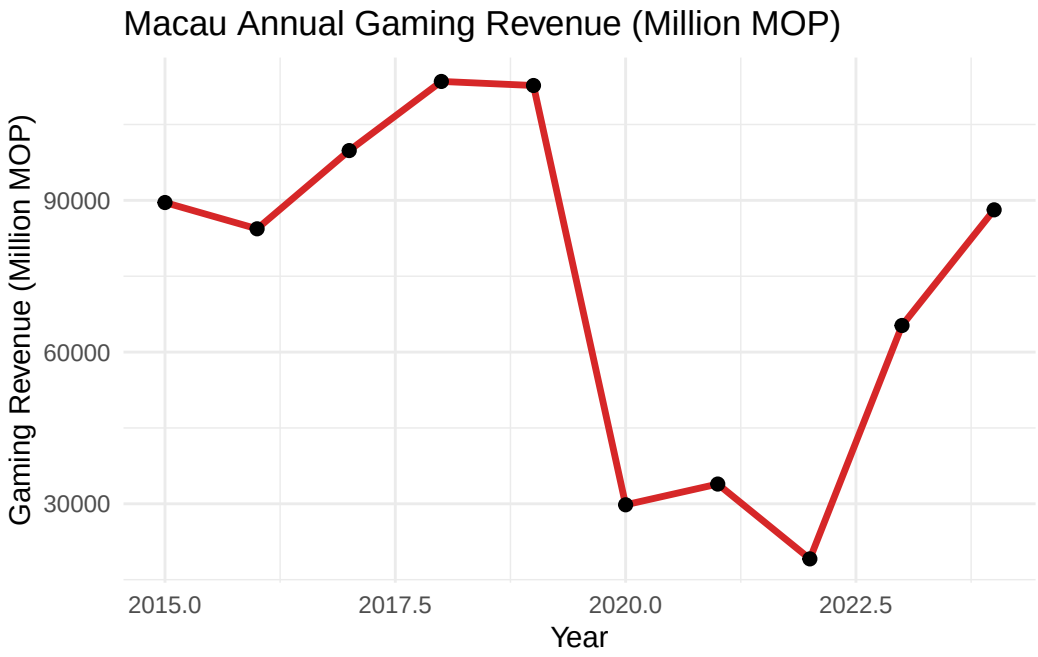
cleandata

```
library(readxl)
library(dplyr)
library(stringr)

gaming_raw <- read_excel("dsec2.xlsx")

gaming <- gaming_raw %>%
  slice(-(1:3)) %>%                        # remove header notes
  rename(year_raw = 1, gaming_mop = 2) %>%
  mutate(
```

```
    year = as.numeric(str_extract(year_raw, "\\d+")),
    gaming_mop = suppressWarnings(as.numeric(gaming_mop))
  ) %>%
  filter(!is.na(year), !is.na(gaming_mop)) %>%
  select(year, gaming_mop) %>%
  arrange(year)
```

analysis

```
library(ggplot2)

ggplot(gaming, aes(year, gaming_mop)) +
  geom_line(linewidth = 1.2, color = "#d62728") +
  geom_point(size = 2) +
  theme_minimal() +
  labs(
    title = "Macau Annual Gaming Revenue (Million MOP)",
    x = "Year",
    y = "Gaming Revenue (Million MOP)"
  )
```



External Merchandise Trade

Although domestic exports represent only a small share of Macau's overall economy, they reflect the performance of the city's local manufacturing and re-export sectors. Tracking export levels helps illustrate how smaller non-gaming industries respond to economic cycles and external demand. Including this indicator allows for a more balanced understanding of Macau's economic diversification efforts.

cleandata

```
trade_raw <- read_excel("dsec3.xlsx", col_names = FALSE) %>%
  rename(
    period = ...1,
    trade_mop = ...2
  )
```

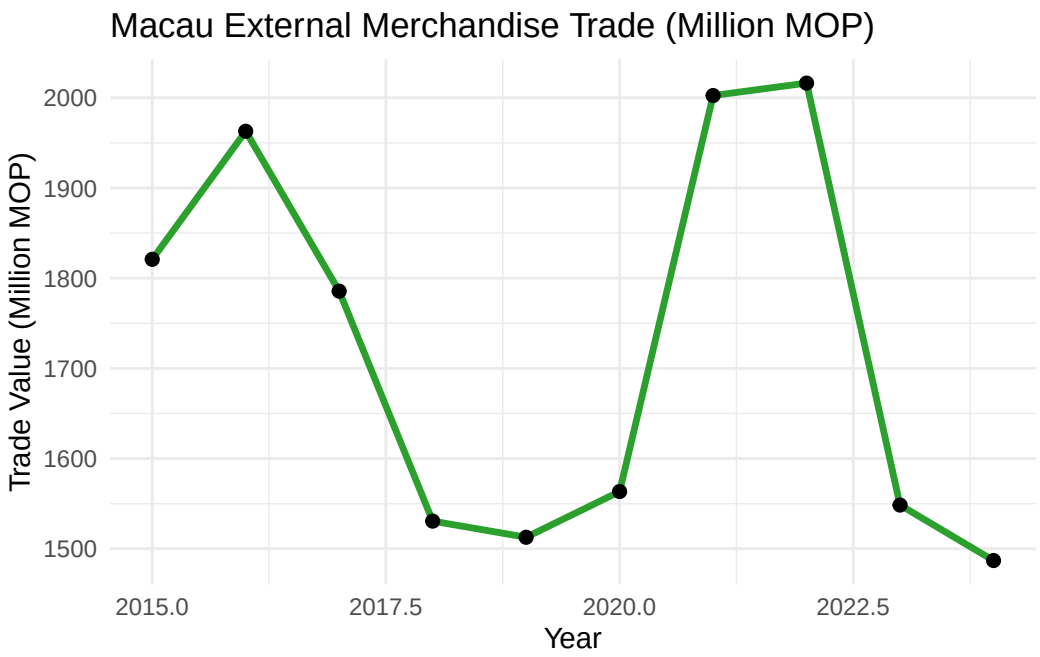
```
New names:
* `` -> `...1`
* `` -> `...2`
* `` -> `...3`
* `` -> `...4`
```

```
trade <- trade_raw %>%
  filter(str_detect(period, "^\\d{4}$")) %>%
  mutate(
    year = as.numeric(str_extract(period, "\\d{4}")),
    trade_mop = as.numeric(str_remove_all(trade_mop, ","))
  ) %>%
  select(year, trade_mop) %>%
  arrange(year)
```

analysis

```
ggplot(trade, aes(year, trade_mop)) +
  geom_line(linewidth = 1.2, color = "#2ca02c") +
  geom_point(size = 2) +
  theme_minimal() +
  labs(
```

```
    title = "Macau External Merchandise Trade (Million MOP)",
    x = "Year",
    y = "Trade Value (Million MOP)"
  )
```



Analysis

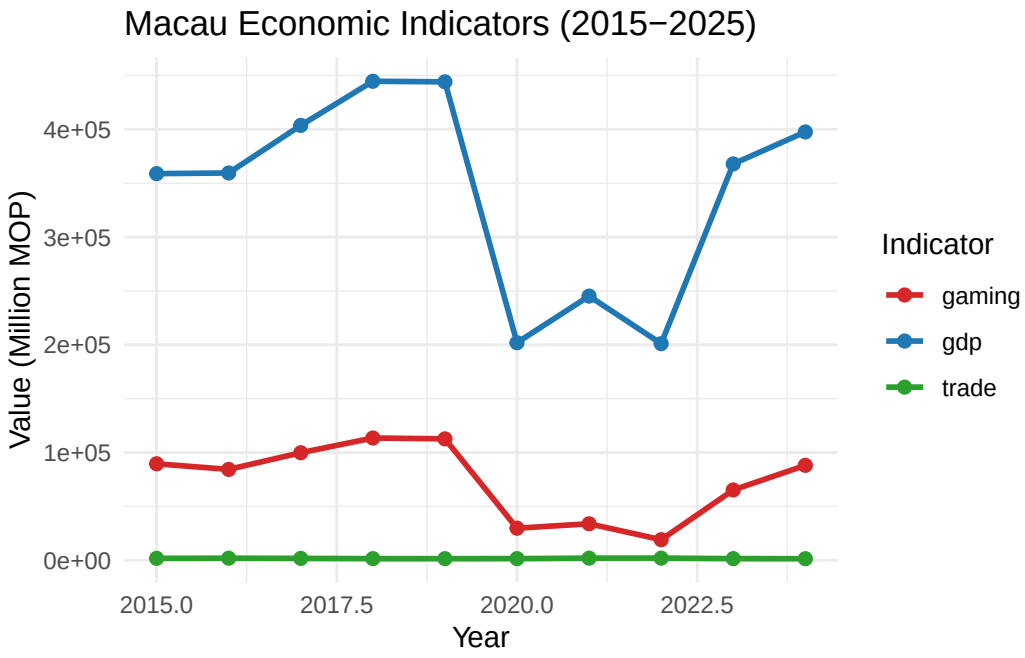
```
gdp <- gdp %>% filter(year >= 2015, year <= 2025)
gaming <- gaming %>% filter(year >= 2015, year <= 2025)
trade <- trade %>% filter(year >= 2015, year <= 2025)
econ_all <- gdp %>%
  rename(gdp = gdp_mop) %>%
  left_join(gaming %>% rename(gaming = gaming_mop), by = "year") %>%
  left_join(trade %>% rename(trade = trade_mop), by = "year")
econ_all
```

```
# A tibble: 10 x 4
    year    gdp gaming trade
   <dbl>  <dbl>  <dbl> <dbl>
 1  2015 358849  89573 1821.
```

```
 2  2016 359497  84375 1963.
 3  2017 403684  99845 1786.
 4  2018 444604 113512 1531.
 5  2019 444079 112710 1513.
 6  2020 201964  29808 1563.
 7  2021 245241  33910 2002.
 8  2022 201060  19115 2016.
 9  2023 367904  65258 1548.
10  2024 397560  88127 1487.
```

plot

```
library(tidyr)

econ_long <- econ_all %>%
  pivot_longer(cols = c(gdp, gaming, trade),
               names_to = "indicator",
               values_to = "value")

ggplot(econ_long, aes(year, value, color = indicator)) +
  geom_line(linewidth = 1) +
  geom_point(size = 2) +
  theme_minimal() +
  scale_color_manual(values = c(
    "gdp" = "#1f77b4",
    "gaming" = "#d62728",
    "trade" = "#2ca02c"
  )) +
  labs(
    title = "Macau Economic Indicators (2015-2025)",
    x = "Year",
    y = "Value (Million MOP)",
    color = "Indicator"
  )
```



Conclusion

Overall, this project demonstrates how publicly available economic and demographic data can be integrated with spatial visualization and interactive tools to support exploratory analysis. The combination of static summaries and Shiny-based sensitivity analysis provides an intuitive framework for examining structural patterns in Macau's economy while highlighting the importance of data assumptions in applied analysis.

Future work

Future extensions could incorporate sub-regional population data or alternative spatial units if available.