In [1]:
```python
import pandas as pd
```

1. Use S&P 500 futures tick data taken fromhttps://www.kaggle.com/datasets/finnhub/sp-500-futures-tick-data-sp.

Save it as SP.csv. Remove the rows with 0 volume and then proceed.

In [2]:
```python
sp = pd.read_csv('../data/SP.csv')
```

In [3]:
```python
# Convert time column to string format first, then combine
sp['date_time'] = pd.to_datetime(sp['date'].astype(str) + ' ' + sp['time'].astype(s
```

In [4]:
```python
# sp_process for later use
sp = sp[['date_time', 'price', 'volume']].copy()
```

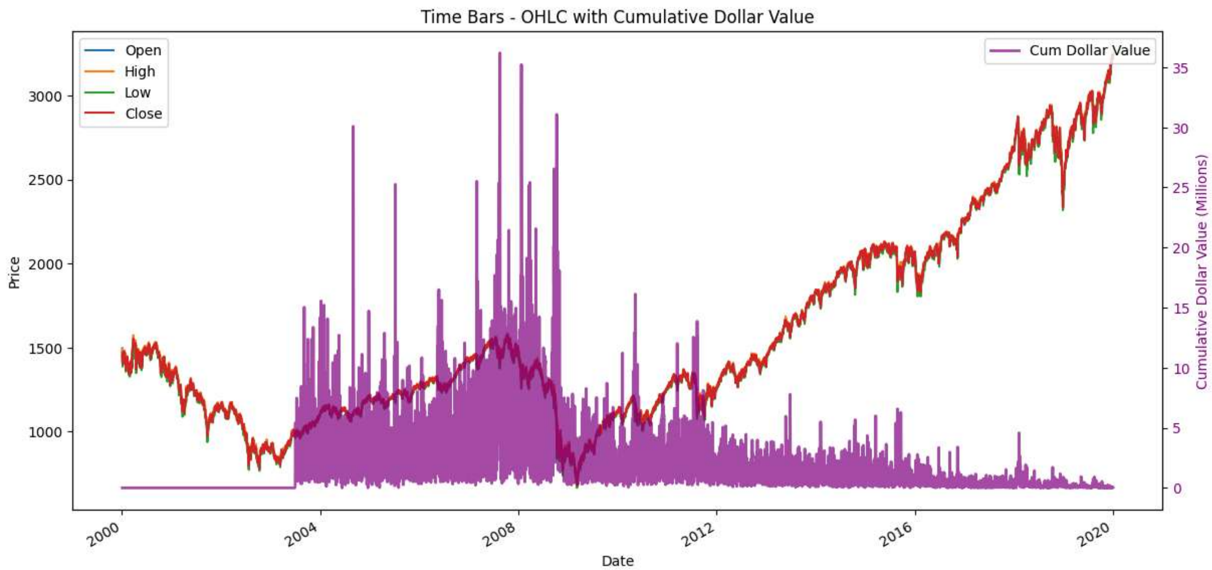
In [5]:
```python
#TIME BARS Using MLFinLab
from mlfinlab.data_structures import time_data_structures

time_bars = time_data_structures.get_time_bars(
    sp, resolution="D", verbose=False
)
```

In [6]:
```python
len(time_bars)
```

Out[6]: 5977

In [7]:
```python
import matplotlib.pyplot as plt

# Plot all OHLC data with cum_dollar_value on secondary axis
fig, ax = plt.subplots(figsize=(14, 7))

# Plot OHLC on left axis
time_bars[['open', 'high', 'low', 'close']].plot(ax=ax)

# Create secondary y-axis for cum_dollar_value (in millions)
ax2 = ax.twinx()
(time_bars['cum_dollar_value'] / 1e6).plot(ax=ax2, color='purple', linewidth=2, lab

# Labels and Legend
ax.set_xlabel('Date')
ax.set_ylabel('Price')
ax2.set_ylabel('Cumulative Dollar Value (Millions)', color='purple')
ax2.tick_params(axis='y', labelcolor='purple')

plt.title('Time Bars - OHLC with Cumulative Dollar Value')
ax.legend(['Open', 'High', 'Low', 'Close'], loc='upper left')
```

```
ax2.legend(loc='upper right')
plt.show()
```



Get rid of the Zero Volume data

But note also that the volume is farly steady between 2004 and 2008 the gradually trails off. I think the volume migrated from the ES contract to SPY

In [8]:
```
#sp = sp.loc[pd.to_datetime(sp['date'].astype(str)) > pd.Timestamp('2003-06-30')].c
#sp = sp_read.loc[pd.to_datetime(sp_read['date'].astype(str)) >= pd.Timestamp('2004
sp = sp[sp['volume'] != 0]
```

In [9]:
```
sp.head()
```

Out[9]:

	date_time	price	volume
2812944	2003-06-30 23:00:06	971.9	1
2812945	2003-06-30 23:00:14	972.0	1
2812946	2003-06-30 23:04:16	972.0	1
2812947	2003-06-30 23:04:34	972.0	9
2812948	2003-06-30 23:05:02	972.0	91

In [10]:
```
#Check for zero volume rows
print(f"Rows with Volume = 0: {(sp['volume'] == 0).sum()}")
```

```
Rows with Volume = 0: 0
```

In [11]:
```
sp.describe(include='all')
```

Out[11]:

	date_time	price	volume
count	6498085	6.498085e+06	6.498085e+06
mean	2008-08-20 17:09:27.000917760	1.275834e+03	1.800299e+00
min	2003-06-30 23:00:06	6.711000e+02	1.000000e+00
25%	2006-06-12 04:50:56	1.113900e+03	1.000000e+00
50%	2008-06-05 06:20:22	1.251000e+03	1.000000e+00
75%	2010-07-16 06:26:15	1.389700e+03	2.000000e+00
max	2019-12-31 02:21:45.011000	3.253500e+03	4.086000e+03
std	NaN	2.756042e+02	9.512023e+00

Create sp_processed and limit the data to between 2010 and 2016

In [12]:
```
# sp_process for later use
sp_processed = sp[['date_time', 'price', 'volume']].copy()

# Filter to only 2010-2016
sp_processed = sp_processed[(sp_processed['date_time'] >= '2010-01-01') &
                            (sp_processed['date_time'] < '2016-01-01')]
```

Look at Time Bars for cleaned up data

In [13]:
```
#TIME BARS Using MLFinLab

time_bars = time_data_structures.get_time_bars(
    sp_processed, resolution="D", verbose=False
)
```

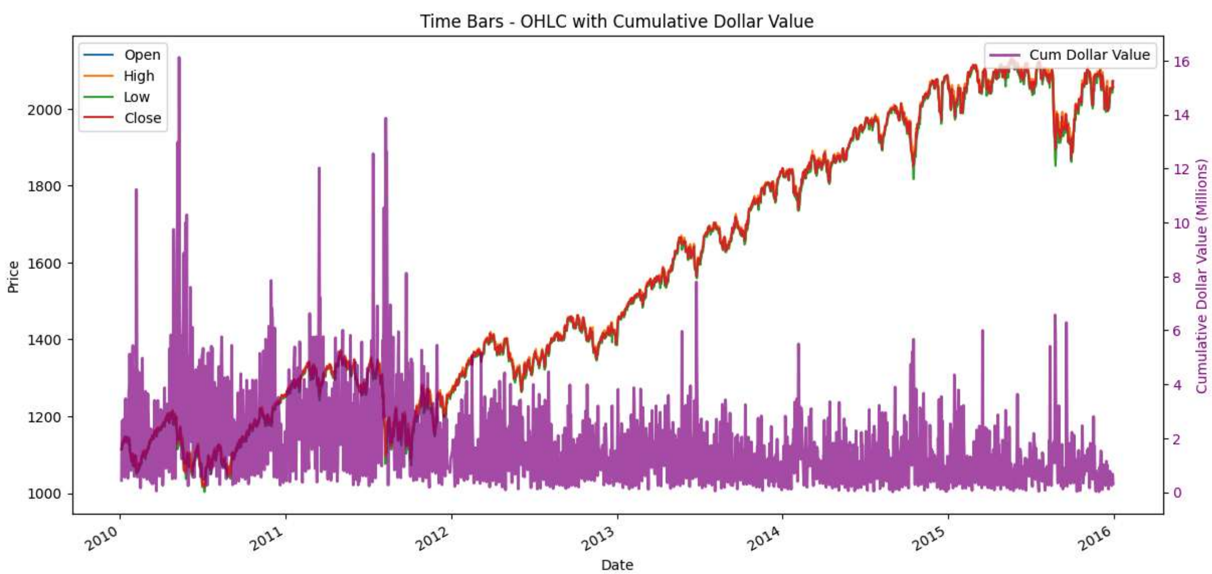
In [14]:
```
# Plotly plot with controls
import plotly.graph_objects as go

fig = go.Figure(data=[go.Candlestick(x=time_bars[:].index,
                open=time_bars['open'],
                high=time_bars['high'],
                low=time_bars['low'],
                close=time_bars['close'])])
fig.update_layout(title='Time Bars - Candlestick Chart', xaxis_title='Date', yaxis_
fig.show()
```

In [15]:
```
len(time_bars)
```

Out[15]: 1862

Plot time_bars vs cum_dollar_value

In [16]:
```
# Plot all OHLC data with cum_dollar_value on secondary axis
fig, ax = plt.subplots(figsize=(14, 7))

# Plot OHLC on left axis
time_bars[['open', 'high', 'low', 'close']].plot(ax=ax)

# Create secondary y-axis for cum_dollar_value (in millions)
ax2 = ax.twinx()
(time_bars['cum_dollar_value'] / 1e6).plot(ax=ax2, color='purple', linewidth=2, lab

# Labels and Legend
ax.set_xlabel('Date')
ax.set_ylabel('Price')
ax2.set_ylabel('Cumulative Dollar Value (Millions)', color='purple')
ax2.tick_params(axis='y', labelcolor='purple')

plt.title('Time Bars - OHLC with Cumulative Dollar Value')
ax.legend(['Open', 'High', 'Low', 'Close'], loc='upper left')
ax2.legend(loc='upper right')
plt.show()
```



2. Form dollar bars for the data from Exercise 1 above.

In [17]:
```
from mlfinlab.data_structures import standard_data_structures
# Compare different thresholds
for threshold in [1e6, 1.5e6, 2e6, 5e6]:
    bars = standard_data_structures.get_dollar_bars(sp_processed, threshold=thresho
    print(f"Threshold ${threshold/1e6:.1f}M: {len(bars)} bars")
```

```
Threshold $1.0M: 3811 bars
Threshold $1.5M: 2543 bars
Threshold $2.0M: 1908 bars
Threshold $5.0M: 763 bars
```

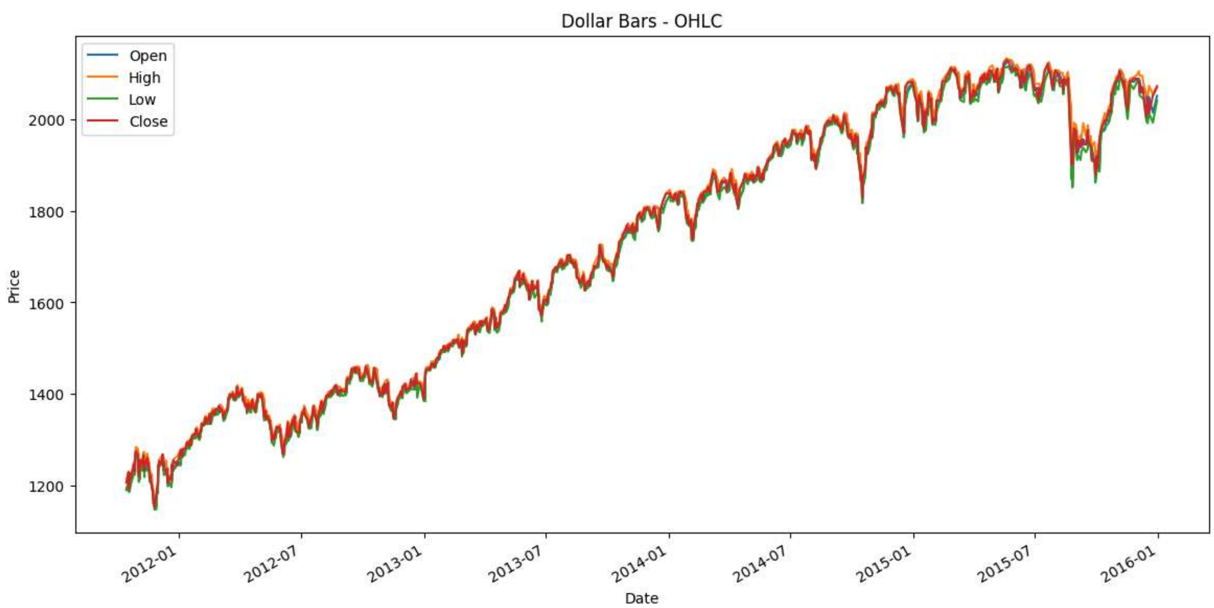
Set Threshold to $2.0 million

In [18]:
```
#DOLLAR BARS Using MLFinLab

dollar_bars = standard_data_structures.get_dollar_bars(
    sp_processed, threshold=2000000, batch_size=1000000, verbose=False
)

print(f"Dollar bars shape: {dollar_bars.shape}")
```

```
Dollar bars shape: (1908, 9)
```

Look at last 1000

In [19]:
```
# DOLLAR BARS Plot OHLC data Last 1000
fig, ax = plt.subplots(figsize=(14, 7))
dollar_bars[-1000:][['open', 'high', 'low', 'close']].plot(ax=ax)
plt.title('Dollar Bars - OHLC')
plt.xlabel('Date')
plt.ylabel('Price')
plt.legend(['Open', 'High', 'Low', 'Close'])
plt.show()
```



Look at first 500

In [20]:
```
# Dollar Bars Analysis

fig = go.Figure(data=[go.Candlestick(x=dollar_bars[:500].index,
                open=dollar_bars['open'],
                high=dollar_bars['high'],
                low=dollar_bars['low'],
                close=dollar_bars['close'])])
fig.update_layout(title='Dollar Bars - Candlestick Chart', xaxis_title='Date', yaxi
fig.show()
```

In [21]:
```
'''Snippet 3.1 - Daily Volatility Estimates'''

# def getdailyVol(close, span0=100):
#     df0 = close.index.searchsorted(close.index - pd.Timedelta(days=1))
#     df0 = df0[df0 > 0]
#     df0 = pd.Series(close.index[df0 - 1], index=close.index[close.shape[0] - df0.
#     df0 = close.loc[df0.index]/close.loc[df0.values].values - 1.0
#     df0 = df0.ewm(span=span0).std()
#     return df0
```

Out[21]: 'Snippet 3.1 - Daily Volatility Estimates'

In [22]:
```
# From GPT-5

def get_daily_vol(close, span=100, lookback=pd.Timedelta('1D')):
    # Ensure we are working with a datetime index Series
    if isinstance(close, pd.DataFrame):
        if 'close' not in close.columns:
            raise ValueError("DataFrame must have a 'close' column.")
        close = close['close']
    if 'date_time' in getattr(close, 'columns', []):
        close = close.set_index('date_time')['close']
    close = close.sort_index()
    if not isinstance(close.index, pd.DatetimeIndex):
        raise ValueError("Input series must have a DatetimeIndex.")

    prev = close.index.searchsorted(close.index - lookback)
    prev = prev[prev > 0]
    prev_ts = pd.Series(close.index[prev - 1], index=close.index[-prev.shape[0]:])
    returns = close.loc[prev_ts.index] / close.loc[prev_ts.values].values - 1
    return returns.ewm(span=span).std()
```

In [23]:
```
'''Snippet 2.4 the Symetric CUSUM Filter'''

# def getTEvents(gRaw, h):
#     tEvents, sPos, sNeg = [], 0, 0
#     diff = gRaw.diff()
#     for i in diff.index[1:]:
#         sPos = max(0, sPos + diff.loc[i])
#         sNeg = min(0, sNeg + diff.loc[i])
#         # Use dynamic threshold if h is a Series, skip if not available
#         if isinstance(h, pd.Series):
#             if i not in h.index:
#                 continue
#             threshold = h.loc[i]
#         else:
#             threshold = h
#         if sNeg < -threshold:
#             sNeg = 0
#             tEvents.append(i)
#         elif sPos > threshold:
#             sPos = 0
#             tEvents.append(i)
#     return pd.DatetimeIndex(tEvents)
```

Out[23]: 'Snippet 2.4 the Symetric CUSUM Filter'

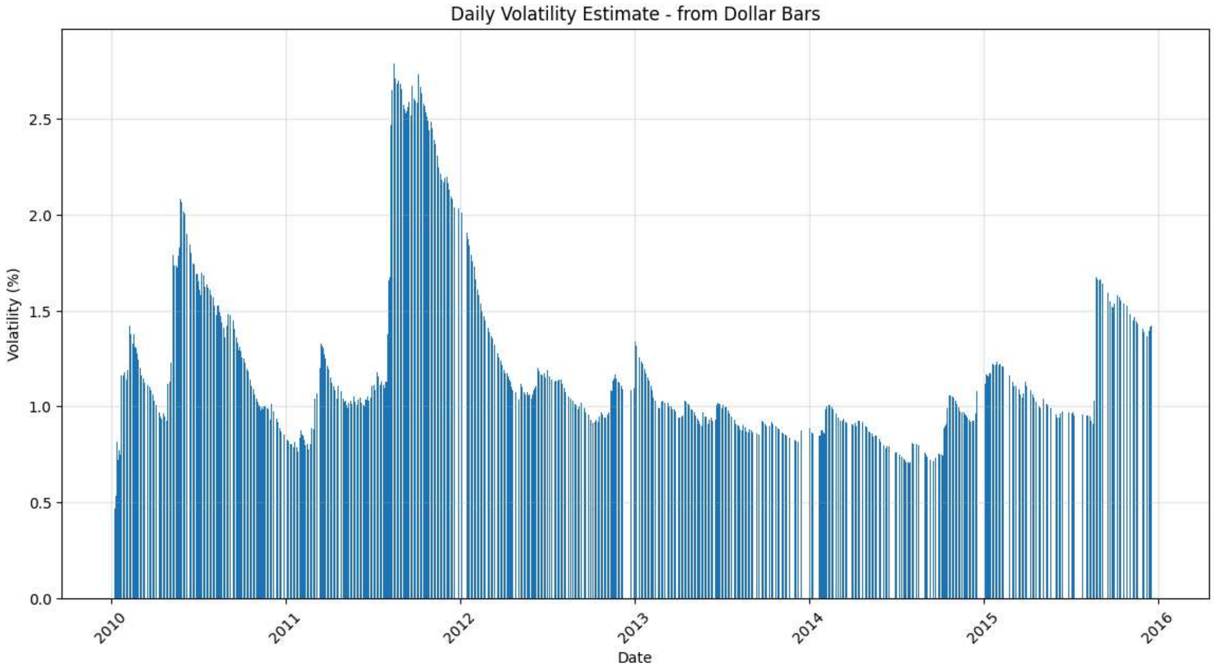
In [24]:
```
'''Modified Snippet 2.4 the Symetric CUSUM Filter'''
# From GPT-5
def get_t_events(price, h):
    price = price.sort_index()
    if isinstance(h, pd.Series):
        h = h.reindex(price.index)
    diff = price.diff().dropna()
    t_events, s_pos, s_neg = [], 0.0, 0.0

    for t in diff.index:
        s_pos = max(0.0, s_pos + diff.loc[t])
        s_neg = min(0.0, s_neg + diff.loc[t])
        threshold = h.loc[t] if isinstance(h, pd.Series) else h
        if pd.isna(threshold):
            continue
        if s_neg < -threshold:
            s_neg = 0.0
            t_events.append(t)
        elif s_pos > threshold:
            s_pos = 0.0
            t_events.append(t)
    return pd.DatetimeIndex(t_events)
```

I originally looked at daily vol from Time Bars then switched to Dollar Bars

too lazy to update the code.

In [25]:
```
dv = get_daily_vol(dollar_bars['close'], span=100)
dv_dollar = dv
```

In [26]:
```
fig, ax = plt.subplots(figsize=(14, 7))
ax.bar(dv.index, dv * 100, width=1)
plt.title('Daily Volatility Estimate - from Dollar Bars')
plt.xlabel('Date')
plt.ylabel('Volatility (%)')
plt.grid(True, alpha=0.3)
plt.xticks(rotation=45)
plt.show()
```



This took some figuring

(a) Apply a symmetric CUSUM filter (Chapter 2, Section 2.5.2.1) where the threshold is the standard deviation of daily returns (Snippet 3.1).

```
get_daily_vol is Snippet 3.1
```

dv_dollar is percent change but the CUMSUM is looking for dollar change.

Use threshold_dollars

In [27]:
```
threshold_dollars = dv_dollar * dollar_bars['close']
devents = get_t_events(dollar_bars['close'], threshold_dollars * 1)
```

In [28]:
```
# Dollar Bars Analysis with date range control
start_date = '2010-01-01'
end_date = '2010-06-01'

# Filter data by date range
mask = (dollar_bars.index >= start_date) & (dollar_bars.index < end_date)
dollar_bars_filtered = dollar_bars[mask]

fig = go.Figure(data=[go.Candlestick(x=dollar_bars_filtered.index,
                open=dollar_bars_filtered['open'],
                high=dollar_bars_filtered['high'],
                low=dollar_bars_filtered['low'],
                close=dollar_bars_filtered['close'])])

# Add devents overlay
devents_subset = devents[devents.isin(dollar_bars_filtered.index)]
```

```
if len(devents_subset) > 0:
    devent_prices = dollar_bars.loc[devents_subset, 'close']
    fig.add_trace(go.Scatter(
        x=devents_subset,
        y=devent_prices,
        mode='markers',
        marker=dict(color='red', size=8, symbol='x'),
        name='T-Events'
    ))

fig.update_layout(
    title='Dollar Bars - Candlestick Chart with devents',
    xaxis_title='Date',
    yaxis_title='Price',
    xaxis=dict(
        rangeselector=dict(
            buttons=list([
                dict(count=1, label="1m", step="month", stepmode="backward"),
                dict(count=6, label="6m", step="month", stepmode="backward"),
                dict(count=1, label="1y", step="year", stepmode="backward"),
                dict(step="all")
            ])
        ),
        rangeslider=dict(visible=True),
        type="date"
    )
)
fig.show()
```

(b) Use Snippet 3.4 on a pandas series t1, where numDays=1.

ADDING A VERTICAL BARRIER

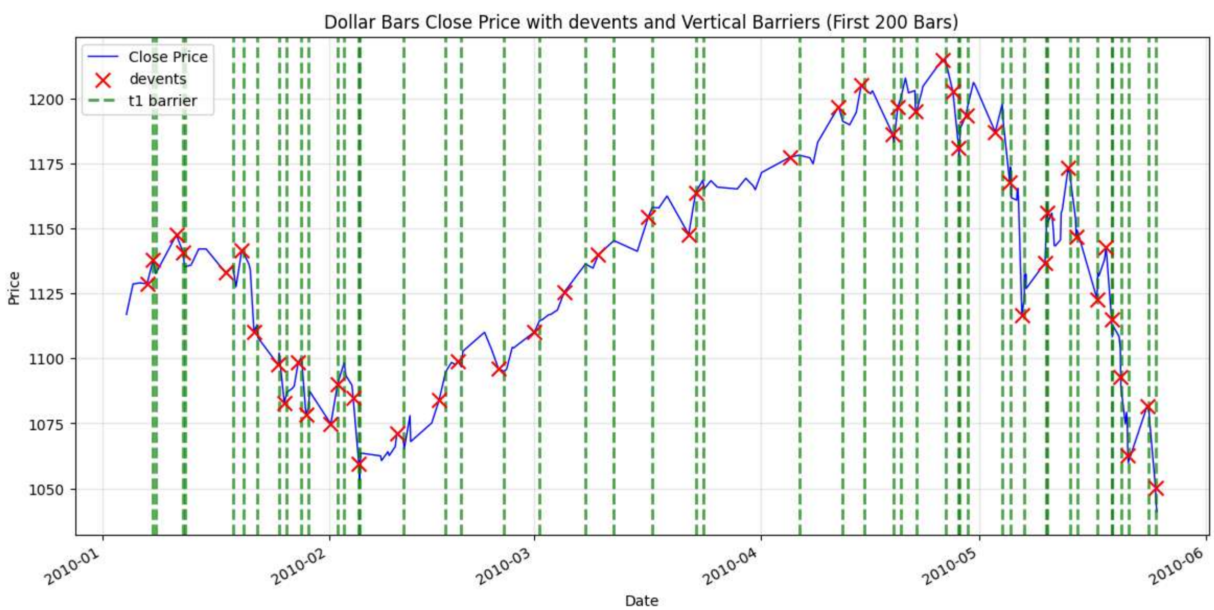
In [29]:

```
close = dollar_bars['close']

'''Snippet 3.4 ADDING A VERTICAL BARRIER - Bar-based instead of time-based'''

numBars = 1  # Number of bars ahead, not days

# For each event, find the bar that is numBars positions ahead
t1_indices = []
t1_values = []

for event in devents:
    event_pos = close.index.get_loc(event)
    t1_pos = min(event_pos + numBars, len(close) - 1)  # Don't go past the end
    t1_indices.append(event)
    t1_values.append(close.index[t1_pos])

t1 = pd.Series(t1_values, index=t1_indices)
```

In [30]:

```
how_many = 200
# Create figure
fig, ax = plt.subplots(figsize=(14, 7))
```

```
# Plot first 50 close prices
dollar_bars['close'][:how_many].plot(ax=ax, label='Close Price', linewidth=1, color

# Filter data to first 50 bars
last_50_dates = dollar_bars[:how_many].index
devents_filtered = devents[devents.isin(last_50_dates)]

# Overlay devents with 'x' markers
if len(devents_filtered) > 0:
    devent_prices = dollar_bars.loc[devents_filtered, 'close']
    ax.scatter(devents_filtered, devent_prices, color='red', marker='x', s=100,
               label='devents', zorder=5)

    # Add vertical lines for t1 barriers
    for t0 in devents_filtered:
        if t0 in t1.index:
            t1_date = t1.loc[t0]
            # Draw vertical line at t1 (removed the date range check)
            ax.axvline(x=t1_date, color='green', linestyle='dashed', alpha=0.7, lin
                       label='t1 barrier' if t0 == devents_filtered[0] else '')

plt.title(f'Dollar Bars Close Price with devents and Vertical Barriers (First {how_
plt.xlabel('Date')
plt.ylabel('Price')
plt.legend()
plt.grid(True, alpha=0.3)
plt.show()

# Debug info
#print(f"devents in range: {len(devents_filtered)}")
#print(f"t1 entries: {t1[t1.index.isin(devents_filtered)]}")
```



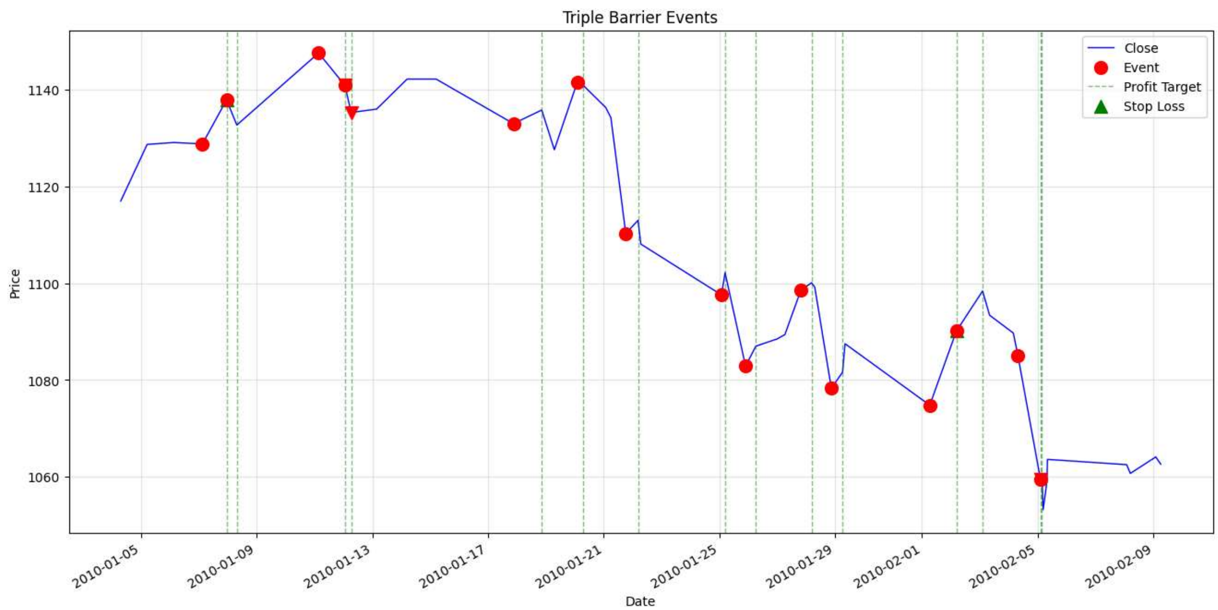
(c) On those sampled features, apply the triple-barrier method, where ptSl=[1,1] and t1 is the series you created in part b.

In [31]:
```
'''Snippet 3.2 TRIPPLE-BARRIER LABELING METHOD'''

def applyPtSlOnT1(close, events, ptSl, molecule):
    events_ = events.loc[molecule]
    out = events_[['t1']].copy(deep=True)
    if ptSl[0] > 0:
        pt = ptSl[0] * events_['trgt']
    else:
        pt = pd.Series(index=events.index) #NaNa
    if ptSl[1] > 0:
        sl = -ptSl[1] * events_['trgt']
    else:
        sl = pd.Series(index=events.index) #NaNa
    for loc, t1 in events_['t1'].fillna(close.index[-1]).items():
        df0 = close[loc:t1]  # path prices
        df0 = (df0 / close[loc] - 1)  # path returns
        out.loc[loc, 'sl'] = df0[df0 < sl.loc[loc]].index.min()  # earliest stop lo
        out.loc[loc, 'pt'] = df0[df0 > pt.loc[loc]].index.min()  # earliest profit
    return out
```

In [32]:
```
# Create events DataFrame
events = pd.DataFrame(index=devents)
events['t1'] = t1  # vertical barrier
events['trgt'] = dv_dollar.reindex(devents)  # target/threshold for each event

# Apply triple barrier
TripleBarrierEvents = applyPtSlOnT1(close, events, ptSl=(1, 1), molecule=devents)
```

In [33]:
```
# Chart with triple barriers
how_many = 50
start_idx = 0

fig, ax = plt.subplots(figsize=(16, 8))

# Plot close prices
dollar_bars['close'][start_idx:start_idx+how_many].plot(ax=ax, label='Close Price',

# Filter events in range
range_dates = dollar_bars[start_idx:start_idx+how_many].index
events_in_range = TripleBarrierEvents[TripleBarrierEvents.index.isin(range_dates)]

for event_time in events_in_range.index:
    event_price = dollar_bars.loc[event_time, 'close']

    # Mark the event
    ax.scatter(event_time, event_price, color='red', marker='o', s=100, zorder=5)

    # Vertical barrier (t1)
    t1_time = events_in_range.loc[event_time, 't1']
    if pd.notna(t1_time):
        ax.axvline(x=t1_time, color='green', linestyle='--', alpha=0.5, linewidth=1

    # Profit target (pt)
    pt_time = events_in_range.loc[event_time, 'pt']
```

```
    if pd.notna(pt_time):
        pt_price = dollar_bars.loc[pt_time, 'close']
        ax.scatter(pt_time, pt_price, color='green', marker='^', s=100, zorder=5)

    # Stop loss (sl)
    sl_time = events_in_range.loc[event_time, 'sl']
    if pd.notna(sl_time):
        sl_price = dollar_bars.loc[sl_time, 'close']
        ax.scatter(sl_time, sl_price, color='red', marker='v', s=100, zorder=5)

plt.title('Triple Barrier Events')
plt.xlabel('Date')
plt.ylabel('Price')
plt.legend(['Close', 'Event', 'Profit Target', 'Stop Loss'])
plt.grid(True, alpha=0.3)
plt.show()
```



(d) Apply getBins to generate the labels.

In [34]:
```
import numpy as np
'''Snippet 3.5 LABELING FOR SIDE AND SIZE'''

def getBins(events, close):
    events_ = events.dropna(subset=['t1'])
    px = events_.index.union(events_['t1'].values).drop_duplicates()
    px = close.reindex(px, method='bfill')

    out = pd.DataFrame(index=events_.index)
    out['ret'] = px.loc[events_['t1'].values].values / px.loc[events_.index].values
    out['bin'] = np.sign(out['ret'])
    return out
```

In [35]:
```
# Merge TripleBarrierEvents with events to get complete information
events_complete = events.copy()
events_complete['sl'] = TripleBarrierEvents['sl']
events_complete['pt'] = TripleBarrierEvents['pt']
```

```
# Determine which barrier was touched first for each event
# The t1 column should reflect whichever barrier was hit first (or vertical barrier
for idx in events_complete.index:
    barriers = [events_complete.loc[idx, 'pt'],
                events_complete.loc[idx, 'sl'],
                events_complete.loc[idx, 't1']]
    # Get the earliest non-NaT barrier
    barriers_valid = [b for b in barriers if pd.notna(b)]
    if barriers_valid:
        events_complete.loc[idx, 't1'] = min(barriers_valid)

# Apply getBins to generate labels
labels = getBins(events_complete, close)
#labels
```

3. On data from Exercise 1 above, use Snippet 3.8 to drop rare labels.

In [36]:
```
# First, check the current label distribution
print("Original label distribution:")
print(labels['bin'].value_counts(normalize=True))
print(f"\nTotal samples: {len(labels)}")
```

```
Original label distribution:
bin
 1.0    0.562384
-1.0    0.433892
 0.0    0.003724
Name: proportion, dtype: float64

Total samples: 537
```

In [37]:
```
'''Snippet 3.8 DROPPING UNDER-POPULATED LABELS'''

def dropLabels(events, minPtc=0.05):

    while True:
        df0 = events['bin'].value_counts(normalize=True)
        if df0.min() > minPtc or df0.shape[0] <= 3:
            break
        print( 'dropped label', df0.argmin())
        events = events[events['bin'] != df0.argmin()]
    return events
```

In [38]:
```
# Apply dropLabels to remove rare labels (less than 5%)
labels_filtered = dropLabels(labels, minPtc=0.05)

print("\n\nFiltered label distribution:")
print(labels_filtered['bin'].value_counts(normalize=True))
print(f"\nRemaining samples: {len(labels_filtered)}")
print(f"Dropped samples: {len(labels) - len(labels_filtered)}")
```

```
Filtered label distribution:
bin
 1.0    0.562384
-1.0    0.433892
 0.0    0.003724
Name: proportion, dtype: float64

Remaining samples: 537
Dropped samples: 0
```